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HEALTH GUIDELINES FOR WATER RESOURCES AND RELATED LAND USE MANAGEMENT

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Health Guidelines for Water Resources and Related Land Use Management

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HEALTH GUIDELINES FOR WATER RESOURCES AND RELATED LAND USE MANAGEMENT

The following report entitled "Health Guidelines for Water Resource and Related Land Use Management" is herein published in a final draft form. These guidelines were initiated by the Water Supply and Sea Resources Program of the U. S. Public Health Service (now the Division of Water Hygiene of the Environmental Protection Agency) in 1967 under partial funding from the North Atlantic Regional study with the purpose of providing a useful document for guiding water resources planning from a health standpoint.

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CHAPTER I - PUBLIC WATER SUPPLY SYSTEMS

In the PHS Drinking Water Standards(1), a water supply is defined to include "the works and auxiliaries for collection, treatment, storage, and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer." A public water supply system is intended to furnish water for drinking, food processing, or other intimate human uses as well as for a variety of commercial, industrial, municipal, and other uses.

The exact definition of a public water supply system differs from State to State, varying as to the number of families or customers served, but for purposes of this document, includes the idea of service to a community and/or the availability of the system for service to the general public.

The protection and safety of a public water supply system depends upon the sanitary environment, quality and quantity of source waters, the effectiveness and reliability of treatment processes, the integrity and capacity of storage and distribution systems, quality control surveillance, and the qualifications and effectiveness of the operating personnel. Details regarding the sanitary maintenance and evaluation for all aspects of public water supply systems is covered in the Manual for Evaluating Public Drinking Water Supplies.(2)

DRINKING WATER AND HEALTH

Provision of adequate quantities of safe water for drinking and other human uses is important to the public health both because contaminated water can produce disease and illness and because the ready availability of safe water can stimulate better personal hygiene thereby resulting in improved health.

The association of health and water is usually connected with massive outbreaks of typhoid fever and other waterborne diseases which occurred over 50 years ago in the United States and Western countries but have since been largely eliminated by improved water treatment and supply practices. However, it is seldom realized that disease outbreaks still stem from contaminated drinking water; from 1946 to 1960, 228 outbreaks of disease or poisoning with 25,984 cases were attributed to drinking water.(3) Additionally, a variety of significant outbreaks affecting thousands of people have occurred more recently, including ill health from hepatitis,(4) salmonellosis,(5) and gastroenteritis.(6) These outbreaks have been associated with breakdowns both in distribution and treatment processes.

The availability of safe water and modern sanitary facilities in individual homes facilitates good personal hygiene practices and is

(1) Reference numbers refer to bibliography at the end of each respective chapter.

accepted as a key feature of modern life. However, many disadvantaged persons in cities, small towns, and rural areas still do not have adequate supplies of safe water and needed sanitary facilities in their homes. A recent study of American Indian communities has shown that the provision of safe water supply and sanitary facilities in the home reduced the incidence of selected diseases.(7)

RELATION OF PUBLIC WATER SUPPLY SYSTEMS TO WATER RESOURCES DEVELOPMENT

The planning and development of reservoir projects should include consideration not only of the quantity needs of municipalities for water, but also the quality aspects. The effect of all water resource developments upon existing public water supplies should also be considered, especially where the effect may be negative.

In choosing between waters of differing quality, preference should be given to the use of the higher quality water for municipal and drinking purposes. Quality considerations should include a sanitary survey and analysis of the involved watershed, an evaluation of raw water quality and an analysis of trends and forecasts regarding future raw water quality and its relationship to planned water pollution control efforts.

The sanitary survey and analysis of the watershed should be performed by sanitary engineers or other public health specialists and should include examination and evaluation of all existing or potential public health hazards and sources of contamination. Elements to considered in the survey would include:

1. Possible development and activity on the watershed and possible means for control thereof, such as: residential, industrial, recreation, etc. development; and plans for zoning controls and proposed ownership of the watershed lands, particularly adjacent to the reservoir.

2. Major sources of natural contamination including animals, drainage from swamps, bogs, and mineral deposits, and silt from soil erosion.

3. Major sources of man-made contamination including industrial, farm, municipal, and individual home sources.

The determination of raw water quality is frequently difficult because of lack of data on elements important to drinking water quality, variable conditions in the stream which may cause temporal changes in quality and uncertainty with regard to the effects of impoundment on the water quality. (8) Sampling and analysis of a stream should be planned to include the bacterial, chemical, physical,

and radiochemical measures which are important to drinking water quality and should be of such frequency and timing as to give an accurate portrayal of the stream's water quality. Samples should be analyzed by methods described in Standard Methods for the Examination of Water and Wastewater(9) or by comparably recognized techniques.

Water pollution and river basin authorities should be contacted with regard to trends in contaminant levels and forecasts for the future. Such an analysis could indicate that current problems may be solved prior to the time that stored water would be used for municipal purposes or that new problems would require new attention and solutions.

RAW WATER QUALITY AND TREATMENT

The quality of the source waters will determine the treatment processes required to produce a water that meets the PHS Drinking Water Standards. High water quality may require minimal treatment whereas low quality water may require extensive treatment to produce a potable water. In the economic analysis of reservoir projects consideration should be given to the costs of water treatment in evaluating alternate means for providing municipal water supply. Municipal supply intakes should be constructed with multi-level inlets so that, where stratification occurs, the best quality water can be taken into the system; or provision should be made for mixing so as to prevent stratification.

In the past many drinking water supplies from protected well sources have been served to customers without any treatment. However, instances of back-siphonage and contamination in distribution sytems together with related disease outbreaks, have demonstrated the need for maintaining residual levels of a disinfectant, usually chlorine, throughout the system. Consequently, the minimum recommended treatment for all public water supply systems is disinfection.

Guides herein are for raw water quality which is to be given two categories of treatment, "Disinfection Only" and "Conventional Treatment." However, it is also recognized that certain waters will require intermediate degrees of treatment between "Disinfection Only" and "Conventional Treatment" and that others will require an advanced level of treatment beyond "Conventional Treatment."

A. Disinfection Only

Where ground waters are subject to only low levels of contamination, treatment no greater than disinfection may be adequate.

The raw water quality considered satisfactory for this degree of treatment should meet the following requirements:

1. Bacteriological:

   a. Coliform Group - Less than 100/100 ml as measured by a monthly arithmetic mean.

   b. Fecal Coliform: If fecal coliform density is measured, the above total coliform density may be exceeded, but fecal coliform density should not exceed 20/100 ml as measured by a monthly arithmetic mean.

2. Physical:

   Should meet Public Health Service Drinking Water Standards, including limits as follows:

Turbidity	5 units
Color	15 units
Threshold Odor Number	3

3. Chemical:

   Chemicals present should not exceed the following concentrations:

Substance		Concentration (mg/l)
Arsenic (As)		0.01
Barium (Ba)		1
Boron (B)		1
Cadmium (Cd)		0.01
Carbon Chloroform Extract (CCE)		0.2
Chloride (Cl)		250
Chromium (hexavalent, Cr^{+6})		0.05
Copper (Cu)		1
Cyanide (CN)		0.01
Detergents (Methylene Blue Active Substances)		0.5
Fluoride (F)		
50.0-53.7°F	Annual average of	1.7
53.8-58.3°F	maximum daily air	1.5
58.4-63.8°F	temperatures	1.3
63.9-70.6°F		1.2
70.7-79.2°F		1.0
79.3-90.5°F		0.8
Iron (Fe)		0.3
Lead (Pb)		0.05
Manganese (Mn)		0.05
Mercury (Hg)		0.005
Nitrogen (Nitrate + Nitrite) as N		10
Phenols		0.001
Selenium (Se)		0.01

Substance	Concentration (mg/l)
Silver (Ag)	0.05
Sulfate (SO_4)	250
Total Dissolved Solids	500
Uranyl ion (UO_2^{++})	5
Zinc (Zn)	5

4. Radioactivity:

Should meet the Public Health Service Drinking Water Standards including the following:

a. Radium-226 ---------- 3 μμc/liter

Strontium-90 ----------10 μμc/liter

(When these concentrations are exceeded, the water will still be acceptable if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for control action.)

b. In the absence of Strontium-90 and alpha emitters:

Gross beta concentrations --- 1000 μμc/ liter

(When these concentrations are exceeded, the water will be acceptable if more complete analysis indicates that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides as approved by the President on recommendation of the Federal Radiation Council.)

5. Pesticides:

Should not exceed the following limits:

Pesticide	Maximum Permissible Concentration (mg/l)
Endrin	0.003
Aldrin*	0.01
Dieldrin*	0.01
Lindane	0.1
Toxaphene	0.1
Heptachlor**	0.02
Heptachlor Epoxide **	0.02
DDT	0.1

Pesticide	Maximum Permissible Concentration (mg/l)
Chlordane	0.01
Methoxychlor	0.5
Total Organophosphorous and Carbamate Compounds (expressed in terms of Parathion Equivalent Cholinesterase inhibitions)	0.1
2,4,5-TP	0.2
2,4-D	1.0

*The concentration of aldrin and dieldrin in combination should not exceed 0.01 mg/l.

**The concentration of heptachlor and heptachlor epoxide in combination should not exceed 0.02 mg/l.

Disinfection will normally be accomplished by chlorination with a minimum residual to be maintained in distant parts of the distribution system of 0.1 - 0.2 milligrams per liter for free chlorine or 1.0 milligram per liter for chloramines. The Manual for Evaluating Public Drinking Water Supplies gives details regarding chlorination and regarding other types of disinfection treatment.

B. Intermediate Treatment

Many surface waters are of such a degree of purity as usually to meet the recommended guide limits for "Disinfection Only". Such waters would be derived from grassy, wooded terrain including little swamp land or land which is exposed or under cultivation. When adequate storage is provided in reservoirs and strict control of contamination is practiced on the catchment and storage areas, a high quality raw water can usually be obtained.

However, all surface waters are aubject to temporary deterioration in quality through increased levels of turbidity, algae growths, and miscellaneous contaminants. Such contaminants will hinder the effectiveness of disinfection treatment and may reduce the aesthetic properties of the water for drinking purposes. All surface waters, therefore, should receive some degree of treatment more extnesive than "Disinfection Only."

Where surface waters meet or come close to meeting the recommended guide limits for "Disinfection Only", they should be given a degree of intermediate treatment such as flocculation, sedimentation, or filtration or some combination of such treatments.

Some ground waters may contain chemicals or other substances which are removable by less than "Conventional Treatment;" these should be given an intermediate degree of treatment appropriate to the raw water quality problem involved. In any case the objective of the treatment will be to provide continuously an adequate quantity of safe water, meeting the Public Health Service Drinking Water Standards.

C. Conventional Treatment

Waters which are too contaminated for treatment by intermediate means will require conventional treatment. This higher degree of treatment is defined to mean pre-disinfection, coagulation, sedimentation, rapid granular filtration, and post-disinfection.

Even though conventional treatment is to be provided, every effort should be made to prevent and control contamination of the raw water source. Where recreational use is permitted on a reservoir, such use should be accompanied by sanitary controls and should be prohibited in a restricted area surrounding the water supply intake. The design of water treatment plants will vary with local circumstances and should be based on quality problems in the water to be treated.

The raw water quality considered satisfactory for conventional treatment should (in addition to meeting the applicable State Water Quality Standards) meet the following"

1. Bacteriological:

   a. Total Coliform Density: Less than 20,000/100 ml as measured by a monthly geometric mean, or

   b. Fecal Coliform Density: If fecal coliform is measured, the above total coliform density may be exceeded but fecal coliform should not exceed 4,000/100 ml as measured by a monthly geometric mean.

2. Physical:

   Elements of Color, Odor, and Turbidity contribute significantly to the treatability and potability of the water.

   Color ---------- 75 units

   (This limit applies only to non-industrial sources; industrial concentrations of color should be handled on a case-by-case basis and should not exceed levels which are treatable by conventional means.

   Threshold Odor Number ---------- 5
   Turbidity ---------- Variable

   (Factors of nature, size, and electrical charge for the different particles causing turbidity require a variable limit. Turbidity should remain within a range which is readily treatable by complete means; it should not overload

the water treatment works; and it should not change rapidly either in nature or in connection where such rapid shifts would upset normal treatment operations.

3. Chemical:

   Since conventional treatment generally produces little reduction in chemical constituents, raw water should meet the limits given for "Disinfection Only".

4. Radioactivity:

   Should meet requirements for radioactivity as shown for "Disinfection Only".

5. Pesticides:

   Should meet requirements for pesticides as shown for "Disinfection Only"

D. Advanced Treatment

Water of poorer quality (but not sewage) should receive advanced treatment as determined by the user's engineer or consultant and should only be used if no raw water supply of better quality is available. The treated water should continuously meet limits of the Public Health Service Drinking Water Standards unless an exception, related to potability and aesthetic properties, is approved by the State agency responsible for public water supply systems. Additional measurements for constituents, not covered in the PHS Drinking Water Standards, may be necessary under these circumstances.

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CHAPTER II - IRRIGATION WITH SEWAGE TREATMENT PLANT EFFLUENT

The use of effluents from municipal sewage treatment facilities in irrigation has long been practiced. Sewage "farming" in the United States began in the late 19th century in Wyoming, Colorado, California, Utah, and Montana. At the present time, extensive sewage farming is done in the arid western states. Because water availability is critical, little attention is given to the bacteriological quality of the water supply. In water-short areas, available streams are subjected to sewage discharges from small communities, cattle feed lot drainage, infrequent stormwater runoff, and return irrigation water. Since the streams are frequently small, these pollution discharges quickly exceed the normal self-purification capacity of the stream and extend the zone of potential health hazard downstream to other water users, generally farmers dependent upon irrigation water. To prevent disease transmission, the use of raw, settled, or undisinfected sewage has been prohibited on vegetables grown for direct human consumption (produce) in most of the States.

Past experience with unrestricted sewage irrigation has demonstrated that disease outbreaks and worm infestations can be caused by contaminated vegetables and fruits. Today, health department restrictions, low levels of population infection, and curative medicine have practically eliminated disease or worm infestations from food contaminated by irrigation practices in the United States. This does not mean, however, that no threat exists from this source. Irrigation will play an important role in providing the higher food production necessary with an expanding population. As more acreage is developed for irrigation, the demand for water will increase, but the quality of water available will often be poor because of greater reuse.

It is well established that disease-causing bacteria, viruses, protozoa, worms, and fungi are found in fecal material, sewage, and sewage polluted water; consequently, they may contaminate the soil and crops with which they come in contact. Animal as well as human wastes are implicated because many species of pathogens can infect both man and animals. The consumption of uncooked foods contaminated with fecal material may cause the spread of disease in livestock as well as human beings. Microorganisms known to be pathogenic for plants can also be isolated from polluted irrigation water, but the role that water and sewage play in plant disease transmission is not yet completely understood.

The diseases most frequently linked with fecal contamination are typhoid and paratyphoid fevers, Salmonella gastroenteritis, bacillary dysentery, cholera, leptospirosis, infectious hepatitis, viral gastroenteritis, and amoebic dysentery. Typhoid fever, cholera, and amoebic dysentery are now practically nonexistent in this country because of

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effective sanitation and water treatment practices. Less common diseases associated with irrigation agriculture are brucellosis, tuberculosis, tularemia, swine erysipelas, coccidiosis, ascariasis, cysticercosis, fascioliasis, schistosomiasis, and hookworm and tapeworm infections. Although the route of infection is usually by ingestion, larvae of hookworms and flukes can enter the body directly through the skin.

The only reliable means for preventing exposure of the public from contaminated produce is prevention of such contamination from occurring. This has been achieved in the past by health department regulations prohibiting the use of night soil and municipal sewage for the irrigation of produce. Improvements in sewage treatment practice and the application of secondary treatment on a wide scale have prompted efforts to obtain approval of the use of treated waters for unlimited irrigation. Health authorities are generally reluctant to accept such use due to the hazards associated with the source of the waters, the unknown factors of pathogen survival, and the inconsistency associated with many treatment plant operators. The conservative approach adopted in these guidelines will generally assure a safe use of the subject water.

The selection of agricultural irrigation water sources should not be based principally on the availability of the water supply, but should also take into full consideration the bacteriological and chemical quality of the water. The scarcity of water supplies of acceptable quality in irrigation areas is fully recognized. Unfortunately, surface waters in arid and semi-arid regions are often small streams with disproportionately large pollutional additions from domestic wastes, sugar beet lagoon discharges, feedlot drainage, and irrigation returns. These additions of low quality water bring varying numbers of pathogenic organisms to irrigation waters and ultimately in contact with field crops. Practical reduction of the public health hazard can be accomplished only through a concept of multiple safeguards designed to prevent raw plant food from contact with and retention of pathogens.

Enforcement of the bacteriological quality guidelines for irrigation water, 1,000 fecal coliforms per 100 ml, recommended by the National Technical Advisory Committee on Water Quality Criteria should result in reduced exposure of raw plant foods to pathogens. Data correlating fecal coliform levels to Salmonella occurrence indicate that the proposed standard is realistic, providing the safeguard measures and sanitary practices described are observed along with the use of water of this quality. The standard represents the best scientific information presently available. Further refinement of the fecal coliform limits for irrigation water awaits additional microbiological and epidemiological studies. Standards have as their primary objective the protection of public health, but may also

recognize the importance of multiple use in water-short areas, and take into account the specific uses for which the water is needed. The fecal coliform level suggested is attainable only at a cost of adequate waste treatment by all stream users.

For special cases, when environmental conditions are hospitable to pathogens, and/or time of exposure to hostile conditions is short, the local or State health departments should make an appropriate determination regarding the water quality to be used for irrigation.

Because receiving streams may be small and of lesser volume than the sewage effluent, secondary treatment and disinfection of domestic sewages are necessary to ensure substantial reductions of pathogens in irrigation waters. Wastes from food processing plants, meat packing plants and sugar beet mills, and runoff from cattle feedlots should be diverted to lagoons and held for 20 to 30 days to reduce the number of pathogens prior to discharge.

The method of water application influences the amount of fecal contamination to which farm crops are exposed. Flooding, spraying, sub-irrigation, and furrow irrigation are used in various agricultural communities. Waters which are not of potable quality should be applied to crops which may be consumed raw by furrow or sub-irrigation to limit contacts of the disease-causing microorganisms with plant surfaces. The use of primary effluent for spray irrigation is not acceptable.

As a further safeguard against exposure to pathogens and their survival on raw plant foods, farm management of irrigation water should include a program of selective application based on the bacteriological quality of available water. Irrigation water from nearby sources could be applied during the various stages of cultivation but should be discontinued four weeks prior to harvest to further diminish the risk from waterborne pathogens. Water applied after this period should be derived from ground water supplies or farm holding ponds.

Preparation of fruits and vegetables at harvest time includes fresh water rinses to remove soil particles and to maintain the quality of leafy vegetables. From harvest to consumption, all water applied to clean and to freshen raw produce must be of drinking water quality. This water should be applied in a continuously flowing stream or spray with no recirculation of spent water through the system.

Equally important as the water quality are the sanitation practices of the farm laborers who cultivate and harvest the crops and of the produce workers who repackage these perishables for market. Adequate toilet and washing facilities should be provided for both. Every effort should be made to instruct the personnel in principles

of hygiene for their own protection and for improvement of the produce. Farm workers must be made aware of the potential dangers of acquiring or spreading disease when working near animals and animal wastes as well as polluted water and soil. Recurring leptospirosis outbreaks in agricultural areas of Israel emphasize some of the hazards associated with irrigation agriculture. In many areas, agricultural workers are in contact with water far exceeding approved bacteriological limits for recreational waters.

MINIMUM RECOMMENDED GUIDELINES FOR USE OF SEWAGE EFFLUENTS FOR IRRIGATION

The practice of irrigation of agricultural crops with sewage effluents raises a number of health questions concerning the bacterial water quality to be used and with regard to vector control. The factors relating to mosquito and other vector problems are primarily those of hydraulics and drainage. These factors are discussed under Chapter V, Vector Control, of this guideline. Recommended water quality criteria for polluted stream waters used for irrigation are presented and adequately discussed in the "Report of the Committee on Water Quality" published by the Department of the Interior and are therefore not covered here.

The recommended guidelines presented below are considered to be the minimum for the direct use of sewage or treated sewage for irrigation. Local and state regulations regarding this usage should be followed if more stringent than these recommendations.

A. Irrigation with Raw Sewage

Raw sewage should not be used for irrigation.

B. Irrigation with Effluent

1. The sewage to be used for irrigation should be treated by stabilization ponds, in series, having a minimum detention period of 20 days with a recommended detention of 30 days or by a minimum of secondary sewage treatment and disinfection.

2. After being treated, the effluent should meet effluent standards or other requirements as established by the State or other agency having jurisdiction for water pollution control but in no case should the bacterial quality exceed 1,000 fecal coliforms per 100 ml.

C. Precautions to be taken before irrigation

Before irrigation with effluent is carried out, the following precautions should be taken:

1. The areas to be irrigated should be clearly designated with signs warning in clear and visible letters that sewage effluent irrigation is being carried out.

2. The pipe network for this effluent irrigation should be completely disconnected from any potable water supply network.

3. All necessary steps should be taken to prevent mosquito and fly breeding in the area to be irrigated.

4. All necessary steps should be taken to prevent the dissemination of odors which may reach residential areas, recreation areas, or other areas in which the public is likely to be present.

5. No spray irrigation with effluent should be carried out less than 200 yards from a residential area or 50 yards from a road.

6. Ridge and furrow irrigation with effluent may be carried out if the distance to residential areas is greater than 100 yards and the distance to roads is greater than 25 yards.

D. Crop limitations for irrigation with effluent

1. Those crops which may be consumed raw and pasture lands should not be irrigated with sewage effluents.

2. Those crops normally eaten cooked or having an outer peel or husk which is normally removed and discarded, crops for industrial use and not used for human consumption, nursery trees, and fodder crops for harvesting may be irrigated with sewage effluent.

E. Irrigation of lawns with effluent

Effluent should be used to irrigate lawns only where the lawns are closed to the public when the effluent is being applied and while the irrigated lawns remain wet from the effluent application.

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CHAPTER III - SHELLFISH GROWING AND HARVESTING WATERS

In the production of shellfish for direct market harvesting, the quality of waters over the shellfish growing areas is of public health importance due to the ability of shellfish to concentrate bacteriological, radiological, or chemical pollutants. The waters of areas approved for the direct market harvesting of shellfish must be free of potentially harmful concentrations of pathogenic microorganisms, radionuclides, heavy metals, pesticides, other potentially toxic organic compounds, and marine toxins.

Sanitary control of shellfish in the United States is conducted through the National Shellfish Sanitation Program, a cooperative enterprise with participation by the Public Health Service, State control agencies, and the shellfish industry. The participants jointly have developed sanitation guidelines for the sanitary control of shellfish growing areas and for harvesting and processing. These guidelines, titled the National Shellfish Sanitation Manual of Operations(1), are revised and amended periodically at National Shellfish Sanitation Workshops. Interim revisions may be made through joint action of the participants in the program. Currently, the program is coordinated by the Shellfish Sanitation Branch, Division of Sanitation Control, Bureau of Foods and Pesticides, U. S. Food and Drug Administration.

CLASSIFICATION OF GROWING AREAS

The sanitary quality of a shellfish growing area is determined by a sanitary survey which includes:

1. A reconnaissance of the watershed to locate and quantify the sources of domestic and industrial pollution that may potentially affect the quality of the growing area.

2. Hydrographic surveys, supported by bacteriological and chemical analyses to determine the course and fate of the pollutants and the residual levels of pollutants in the water over the shellfish beds and the shellfish meats.

Based on the findings of these surveys, the shellfish area is classified into one of four categories, defined in detail in the Manual of Operations, Part I - Sanitation of Shellfish Growing Areas. The following is an abstract of the manual requirements for these four categories:

Approved Areas

Growing areas may be designated as approved when (a) the sanitary survey indicates that pathogenic microorganisms, radionuclides, and/or harmful industrial wastes do not reach the areas in dangerous concentrations, and (b) this is verified by laboratory findings whenever the sanitary survey indicates the need. Shellfish may be taken from such areas for direct marketing.

Satisfactory Compliance - This item will be satisfied when the following criteria are met:

1. The area is not so contaminated with fecal material that consumption of the shellfish might be hazardous, and

2. The area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous, and

3. The median coliform MPN of the water does not exceed 70/100 ml, and not more than 10 percent of the samples ordinarily exceed an MPN of 230/100 ml for a 5-tube decimal dilution (or 330/100 ml, where the 3-tube decimal dilution is used) in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.

The MPN values are based on an assumed normal ratio of coliforms to pathogens and would not be applicable to any situation in which an abnormal ratio of coliforms to pathogens might be present. Consideration must also be given to the possible presence of industrial or agricultural wastes in which there is an abnormal coliform to pathogen ratio.

Conditionally Approved Areas

The suitability of some areas for harvesting shellfish for direct marketing in dependent upon the attainment of an established performance standard by sewage treatment works discharging effluent directly or indirectly to the area. In other cases, the sanitary quality of the area may be affected by seasonal population increases, runoff from farm lands, or sporadic use of a dock or harbor facility. When not adversely affected by these factors, such areas may be classified as conditionally approved.

State shellfish control agencies shall establish conditionally approved areas only when satisfied that (a) all necessary measures have been taken to insure that performance standards will be met and (b) that precautions have been taken to assure that shellfish will

not be marketed from the areas subsequent to any failure to meet performance standards and before the shellfish can purify themselves of polluting microorganisms or chemical pollutants.

Satisfactory Compliance - For information on satisfactory compliance specifications for this classification, the National Shellfish Sanitation Manual of Operations, Part I, should be consulted.

Restricted Area

An area may be classified as restricted when a sanitary survey indicates a degree of pollution which would make it unsafe to harvest the shellfish for direct marketing. Alternatively, the states may classify such areas as prohibited. Shellfish from such areas may be marketed after purification or relaying as provided for in Section D of the Manual.

Satisfactory Compliance - This item will be satisfied when the following water quality criteria are met in areas designated by the states as restricted:

1. The area is so contaminated with fecal materials that direct consumption of the shellfish might be hazardous, but

2. The area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous, and

3. The coliform median MPN of the water does not exceed 700/100 ml and not more than 10 percent of the samples exceed an MPN of 2300/100 ml in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.

4. Shellfish from restricted areas are not marketed without controlled purification or relaying.

Prohibited Areas

An area shall be classified prohibited if the sanitary survey indicates that dangerous numbers of pathogenic microorganisms might reach an area. The taking of shellfish from such areas for direct marketing shall be carefully prohibited. Relaying or other salvage operations shall be carefully supervised to insure against polluted shellfish entering trade channels. Actual and potential growing areas which have not been subjected to sanitary surveys shall automatically be classified as prohibited.

Satisfactory Compliance - This item will be satisfied when:

1. An area is classified as prohibited if a sanitary survey

indicates either of the following degrees of pollution:

a. The area is so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous, and/or

b. The median coliform MPN of the water exceeds 700/100 ml or more than 10 percent of the samples have a coliform MPN in excess of 2300/100 ml.

2. No market shellfish are taken from prohibited areas except by special permit as described in Section D of the Manual.

3. Coastal areas in which sanitary surveys have not been made shall be automatically classified as prohibited.

RADIOACTIVITY

Radioactive wastes entering the water environment constitute a potential hazard to humans through consumption of shellfish which have taken up the radioactive material from the water. The principal potential sources of such materials are the liquid waste discharges from nuclear energy applications such as nuclear power ships or nuclear power plants. Radioactive wastes from these sources may be discharged into shellfish waters at concentrations not exceeding the applicable standards(2) (or comparable State regulations). Due to the accumulation of radionuclides in aquatic food chains (3)(4), it is possible, however, for certain radionuclides to be present in edible portions of human food organisms in quantities sufficient to be of public health concern, even though the concentrations of the radionuclides in water are within permissible limits according to these standards.

The radionuclides of public health significance which may be found in shellfish include the following:

1. Fission products which include radioisotopes of zirconium, ruthenium, iodine, cerium, and strontium.

2. Activation products which include radioisotopes of chromium, manganese, iron, cobalt, copper, and zinc.

A proposed Appendix C, "Interim Guidelines for Radionuclides for Shellfish" was adopted at the 1968 National Shellfish Sanitation Workshop.(5) This document should be consulted for details of surveillance methods and recommended limits of radionuclides in shellfish. Table I presents a list of selected controlling radionuclides and the recommended guide for radioactivity in shellfish for an assumed intake of 50 grams per day. If the concentration of any single nuclide in shellfish reaches the recommended guide value, the shellfish should be released for public consumption only after a comprehensive evaluation

of the dose to the exposed population from all environmental sources shows that the Federal Radiation Council's Radiation Protection Guides(6) will not be exceeded. If more than one nuclide is present in significant amounts, an additional evaluation must be performed as shown in the "Interim Guidelines for Radionuclides in Shellfish."(5)

Table I - Recommended Guides for Selected Radionuclides

Selected Radionuclide	Maximum Permissable Concentration (MPC)w(a) uCi/cc x10^{-4}	Maximum Permissable Radioactivity intake uCi/day	Radiological Guide for Radioactivity in Shellfish (Assuming a 50 g day intake) uCi/g
^{51}Cr	6.67	1.47	0.03
^{54}Mn	0.333	0.0733	0.001
^{58}Co	0.333	0.0733	0.001
^{59}Fe	0.2	0.044	0.0009
^{60}Co	0.167	0.0367	0.0007
^{64}Cu	1.0	0.22	0.004
^{65}Zn	0.333	0.0733	0.001
^{90}Sr	—	0.0002	0.000004
^{95}Zr	0.2	0.044	0.0009
^{103}Ru	0.267	0.0587	0.001
^{106}Ru	0.0333	0.00733	0.0001
^{131}I	—	0.0001	0.000002
^{144}Ce	0.0333	0.00723	0.0001

a. $(MPC)_w$ for 168-hour week multiplied by a factor of 1/30 for exposure of the general population.

From the standpoint of public health, radionuclide levels in shellfish cannot be the only source of radionuclides considered. The basic approach specified by the Federal Radiation Council is to limit total intake of radionuclides from all sources so that Radiation

Protection Guides are not exceeded. Under circumstances in which the concentrations in shellfish remain well below the guideline values, there is no need for public health concern from this vector. If the concentration approach or exceed the guidelines, the public health significance must be evaluated in the context of radionuclide intake from all sources so that the total exposure does not exceed the Radiation Protection Guides.

Control of population exposure from radionuclides occurring in the environment is accomplished either by restriction of the entry of radionuclides into the environment or through measures designed to limit the intake of radionuclides by individuals. Both modes of control involve the consideration of actual or potential concentrations of radioactivity in water or food (shellfish). Controls should be based upon an evaluation of population exposure with regard to the radiological guides. Annual averaging of the daily radioactivity intake via shellfish consumption is sppropriate, except for the special case of accidental release or discharge of major significance.

TRACE METALS

The capacity of shellfish to concentrate certain metals up to many hundreds of times those levels found in their environment means that molluscs exposed to pollution may contain quantities of such metals that might produce toxicities in the human consumer.(7) The human hazard presented by the accumulation of toxic chemicals by shellfish is illustrated by the well-known Minimata disease outbreaks in Japan. (8)(9) Sanitary surveys of shellfish growing areas must include identification of potential sources of pollution containing these metals, supplemented by hydrographic studies and analyses of water and shellfish meats to assure that harmful quantities of these agents do not reach the growing area.

Trace metals are among the most common inorganic wastes. Typical trade wastes such as those from copper plating, copper pickling, and cuprammonium rayon manufacture contribute the greatest amounts of copper to streams and other water bodies. Cadmium occurs as an impurity in zinc-lead ores in phosphate deposits. It is used to alloy with copper, lead, silver, aluminum, and nickel and in electroplating, ceramics, pigmentation, photography, and nuclear reactors. Organic mercury compounds are used in herbicides, fungicides, medicines, slime control in paper mills, and in various chemical processes. Small quantities of methyl mercury continuously discharged from a factory during the production of acetaldehyde was considered to be the causative agent of Minimata disease.

Most trace metals either are not significantly accumulated by shellfish or kill the shellfish before levels hazardous to humans can be accumulated. To date six exceptions to this rule have been determined. Certain shellfish species are known to be capable of accumulating

zinc, copper, cadmium, mercury, lead, and chromium in sufficient quantity to pose health hazards to human beings.

Recent studies in estuaries and in controlled laboratory experiments lead to the following general conclusions on trace metals accumulation by shellfish:

1. Each species has a different pattern of accumulation of specific metals.

2. A seasonal cycle for trace metals levels in shellfish may be expected.

3. Levels of the metals in the overlying water cannot accurately be determined on the basis of the levels in shellfish; they might have been high in the water for a short period of time, or low for a long period of time.

4. The rate of depletion of metals by shellfish is slow, sometimes requiring many months. Because of this, the depuration process, applicable to the removal of bacteria from shellfish is not feasible for the cleansing of shellfish contaminated with metals.

Tolerance limits for metals in shellfish which would protect the human consumer have been the subject of studies. However, the 1968 Shellfish Sanitation Workshop, in discussing a proposed guideline recommended that inclusion of Guides for Trace Metals in Shellfish in Part I of the manual be deferred.(10) In recommending this action, it was the opinion expressed at the workshop that overall knowledge of trace metals in shellfish is insufficient to warrant such guidelines, but surely indicates potential problems.

PESTICIDES

Pesticides reach shellfish growing areas from many sources, including sewage and industrial waste discharge, runoff from land used for agriculture and forestry, the use of herbicides for the control of aquatic vegetation, and the use of pesticides for the control of shellfish predators. Shellfish rapidly accumulate pesticides and herbicides, often to a concentration which is toxic to the molluscs. Surveys of the pesticides content of shellfish in several estuaries in the United States have shown that, in general, the pesticide levels are low; but in certain isolated instances, the concentrations approached those that might be considered hazardous.

The National Shellfish Sanitation Program has adopted guidelines for concentrations of certain pesticides in shellfish.(11) Limits for other pesticides will be included as additional research findings are obtained. The Recommended Guidelines are shown in Table 2.

Table 2
Recommended Guidelines for Pesticide Levels in Shellfish

Pesticide	Concentration in Shellfish (ppm - drained weight)
Aldrin*	0.20
BHC	0.20
Chlordane	0.03
DDT)	
DDE) ANY ONE OR ALL, NOT TO EXCEED	1.50
DDD)	
Dieldrin*	0.20
Endrin*	0.20
Heptachlor*	0.20
Heptachlor Epoxide*	0.20
Lindane	0.20
Methoxychlor	0.20
2,4-D	0.50

* It is recommended that if the combined values obtained for Aldrin, Dieldrin, Endrin, Heptachlor, and Heptachlor Epoxide exceed 0.20 ppm, such values be considered as "alert" levels which indicate the need for increased sampling until results indicate the levels are receding. It is further recommended that when the combined values for the above five pesticides reach the 0.25 ppm level, the areas be closed until it can be demonstrated that the levels are receding.

MARINE BIOTOXINS

Paralytic shellfish poison (PSP, also called Saxitoxin) is produced in certain marine dinoflagellates used as food by shellfish. The toxin, released during digestion by molluscs, is assimilated and migrates to certain specific tissues varying with the species of shellfish. The toxin is retained by the shellfish in concentrations many times greater than it exists in the water. PSP is found in the West Coast areas of the United States, Canada, and Alaska. It also occurs in the Bay of Fundy and the St. Lawrence estuaries on the East Coast. In some areas it occurs seasonally; in other areas, notably Alaska and Canada, it is found during the entire year. The Manual recommends that if the PSP content reaches a level of 80 micrograms per 100 grams of the edible portions of raw shellfish, the area shall be closed to the taking of those edible species of shellfish subject to these toxins.

Another marine biotoxin has been found in shellfish on the Gulf Coast. The occurrence of this toxin in shellfish has been associated with blooms of the dinoflagellate, Gymnodinium breve. Quantitative standards criteria have not been developed to date for this biotoxin in water or shellfish, but State shellfish sanitation control authorities may elect to close shellfish areas to harvesters if the presence of this toxin is detected in shellfish.

REFERENCES

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10. "Task Force Report on Guidelines for Pesticides, Radionuclides, Metals, and Manual Changes for Marine Toxins," Proceedings, Sixth National Shellfish Sanitation Workshop, USDHEW, PHS, pp. 44-45 1969.

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CHAPTER IV - RECREATION AREA DEVELOPMENT

This guideline has been prepared for the use of planners and others interested in water and related land use development. It is intended to serve as an introduction to the factors of concern to health authorities in the development of recreation areas. Winter sports are not considered. Material in PHS Publication No. 1195, Environmental Health Practice in Recreational Areas (1) was heavily used in the preparation of this chapter. This manual should be consulted for additional details.

In many instances the planning, provision, and maintenance of facilities in recreation areas have not kept pace with the rapidly increasing visitor load. As a result optimum use of such areas is not possible and deterioration of overtaxed facilities is frequently encountered. Where facilities such as water supply, sewage disposal, and solid waste handling are inadequate or lacking, the visitors will fend for themselves, often creating conditions which are aesthetically offensive as well as serious environmental health hazards for themselves and neighboring community residents or visitors. Available recreation facilities will need to be at least tripled by the year 2000 to meet the needs of the Nation's exploding population and increased leisure time. Estimates are that adequate environmental health safeguards comprise approximately 30 percent of development costs of new recreation areas. Since these safeguards represent such an appreciable investment, care should be taken in properly planning, constructing, and maintaining adequate facilities.

Adequate consideration of factors influencing the public health can best be achieved through active cooperation between health and recreation agencies. The development and review of plans of proposed developments and facilities including a review of site selection by qualified public health engineers is recommended. A program of periodic surveys and inspection of facilities and their operation in recreation areas should be established by public health and recreation authorities. It is recognized that developments in remote areas, wilderness areas, and low-density use areas will often be served by primitive sanitary facilities.

SITE SELECTION

Sites selected for recreation areas should be well drained, gently sloping, free from topographical or geological hindrances, and suitable for the use and development of a safe and adequate drinking water supply and of sewage disposal works.

Sites should be free from heavy traffic, air pollution sources, and noise sources. Avoiding location near swamps and marshes, where

insects such as mosquitoes may breed and cause severe annoyance and discomfort, will significantly enhance enjoyment and utilization of the area by the visiting public.

Other considerations are:

1. Hazard-free entrance to and exit from the recreation area.

2. Surfaced and looped roadways within the recreation area.

3. Availability of an entomological survey of the area.

4. Preclusion of flooding of the recreations area's sanitary facilities.

5. Control of undergrowth in developed places.

6. Not subject to unusual wind conditions.

WATERSHED MANAGEMENT

Watershed management involves the supervision, regulation, maintenance, and wise use of the aggregate resources of a drainage basin to provide an optimum yield of water of desirable quality, including the control of erosion, pollution, and floods. Because the condition of the soil and the growth it supports have a marked influence on the quality and quantity of water contributed by a watershed, the use of various control measures and management practices is essential to conserve water and land resources and to prevent economic losses to municipal, industrial, and agricultural water supplies, fisheries, and recreation. In carrying out the various functional activities on watershed lands, including grazing of livestock and game, logging, roadbuilding, mining, house-building, fire control, sewage disposal, and recreation, it is essential that satisfactory watershed conditions be preserved.

Of particular concern are:

1. Erosion control both during and following construction.

2. Logging practices.

3. Prevention or overgrazing by livestock and game.

4. Control of the disposal of domestic and industrial liquid and solid wastes in and adjacent to recreation areas and watercourses.

5. Control of mining and ore-processing operations.

6. Evaluation of potential health hazards through consideration of the toxicity, persistence, and exposure factors of pesticides or other chemicals to be used.

7. Prohibition of uncontrolled camping in areas without basic facilities.

WATER SUPPLY (See also Chapter I)

An adequate supply of water under pressure which meets the source and protection, bacteriological, chemical, physical, and radiologocal requirements of the Public Health Service Drinking Water Standards(2) is essential for the convenience, comfort, safety, and health of visitors and resident staff at outdoor recreation areas.

Points which should be considered are:

1. Extension to the recreational area of any State-approved public water supply where feasible.

2. Quality and Quantity of water supplies available.

3. Degree of treatment necessary to provide water meeting the USPHS Drinking Water Standards.

4. Appropriate steps to provide disinfection as well as to prevent chance contamination of hauled water.

5. Completion of a sanitary survey by a qualified person as part of the collection of initial engineering data on the development of the water supply source and its capacity.

6. Design, construction, and supervision of the proposed water facilities to minimize potential vandalism.

7. Qualified supervision, operation, and maintenance of the water treatment equipment.

8. Protection of the water quality through the design, construction, and maintenance of the distribution system.

9. Design system to permit emergency operations.

SEWAGE DISPOSAL

Safe disposal of human and domestic wastes in recreation areas is necessary for the preservation of the surface and ground waters and the restoration of such waters to the best possible condition consistent with public health and welfare. Proper sewage disposal

prevents damage caused by sewage to the propagation and preservation of fish and wildlife and is essential to protect the visiting public, employees, and nearby communities from diseases transmitted through sewage.

Some important health-related factors are:

1. Provision of a properly designed, constructed, and supervised water-carried sewage disposal system. Experience has shown that pit toilets are a poor second choice and should only be used for remote and lightly used recreation areas.

2. Locating outfalls to minimize the potential effects of sewage effluents.

3. Proximity of septic tank and subsurface disposal systems to buildings, beaches, camping and picnic areas, and water supply systems.

4. Properly planned sludge disposal.

5. Plans for the installation of sewage disposal facilities must provide for adequate operation and maintenance.

PLUMBING

Plumbing includes "the practice, materials, and fixtures used in the installation, maintenance, extension, and alteration of all piping, fixtures, appliances, and appurtences in connection with any of the following: sanitary drainage or storm drainage facilities, the venting system, and the public or private water supply systems within or adjacent to any building structure, or conveyance; also the practice and materials used in the installation, maintenance, extension, or alteration of storm water, liquid waste, or sewerage and water supply systems of any premises to their connection with the public sewer system (or public water system) or other acceptable disposal facility."(3)

In planning the following should be considered:

1. The minimum number of plumbing fixtures should be based upon peak visitor day use (see Table 1).

2. Materials used and their installation should conform to the minimum standards of the National Plumbing Code (as revised) or to local and State codes if they are more restrictive.

BUILDING AND HOUSING HYGIENE

Housing of a healthful quality must provide for fulfillment of the physiological needs of man, which include: a thermal environment

Table 1

SANITARY FACILITIES FOR RECREATION AREAS (4)

Facility	Waterclosets		Urinals	Lavatories	Showers
	Male	Female	Male		
Swimming Pools*	1/75	1/50	1/75	1/100 males 1/100 females	1/50 males 1/50 females (minimum of 2)
Campground Sites					
1-20	1	2	1	2	
21-30	2	3	2	4	
Picnic Areas					
Parking					
1-40	1	2	1	2	
41-80	2	4	2	4	
81-120	3	6	3	6	

Each comfort station should be designed to provide service for sites no further than 500 feet away.

*One drinking fountain, not installed in toilet room, should be provided.

that not only is conducive to good health but is comfortable and promotes efficiency of living; air that is chemically pure and free from objectionable odors; humidity that is healthful and comfortable; and air movement that will provide the necessary air changes to assist in maintaining the desired thermal conditions and air purity. Housing should be free of noise that may impair health. Lighting should be quantitatively and qualitatively adequate, including both natural and artificial sources. All buildings and dwelling units should be constructed and maintained in accordance with the minimum requirements set forth in the "APHA-PHS Recommended Housing Maintenance and Occupancy Ordinance"(5) or requirements that are substantially equivalent. The "Basic Principles of Housing and its Environment"(6) is another good reference in the field of housing. Those concerned with the design, operation, and maintenance of public buildings should consult these references for more complete coverage of this subject. Plans and specifications covering housing, dormitories, camps, hotels, restaurants, and similar facilities should be submitted to the appropriate authorities having jurisdiction for review and recommendations.

Some of the more important aspects of housing not covered elsewhere in this Guideline are:

1. Provision of adequate openable window area for habitable rooms.

2. Provision of adequate outlets where electric service is available.

3. Provision of adequate safe heating facilities.

4. Provision of screens for doors and openable windows during seasons when it is necessary to protect against mosquitoes, flies, and other insects.

5. Protection of buildings against rodent entry.

6. Construction of water closet compartment and bathroom floor surfaces of material impervious to wear.

MILK AND FOOD SANITATION

Despite the progress which has been achieved in food protection programs, foodborne illness continues to be a major public health problem. The incidence of such illness can be reduced by the application of the basic principles of food protection. To achieve this on a day-to-day basis, however, better understanding on the part of many food service employees and employers must be developed, and this in turn will necessitate a maximum of cooperation between public health agencies and the food service industry. The need for even greater attention to this problem in recreation areas is due to the seasonal operation of many areas and the widely fluctuating visitor

load that must be accomodated by food service facilities provided. Seasonal employees who lack adequate training in good food handling practices introduce additional hazards. The applicable State and local milk sanitation laws and regulations and the Public Health Service "Grade "A" Pasteurized Milk Ordinance"(7) should be followed for the dispensing of milk and milk products. The "Food Service Sanitation Manual"(8) including "A Model Food Service Sanitation Ordinance and Code, 1962 Recommendations of the Public Health Service" is a basic reference in the field of food sanitation. Where ice is produced for public use the "Sanitary Standard for Manufactured Ice - 1964 Recommendations of the Public Health Service"(9) should be applied. A basic reference for the dispensing of foods and beverages is "The Vending of Foods and Beverages",(10), a sanitation ordinance and code recommended by the Public Health Service. Before construction of a food service establishment is initiated, properly prepared plans and specifications showing layout, arrangement, and construction materials and the location, size, and type of fixed equipment and facilities should be submitted for approval to the health authority having jurisdiction.

SOLID WASTE DISPOSAL (See also Chapter VI)

Public health problems are often associated with improper storage, collection, and disposal of solid waste in recreation areas. Experience has shown that the application of the basic principles of sanitation to solid waste handling results in substantial reductions in fly, rodent, and other insect problems.(11) Inadequate handling and disposal of solid wastes may also result in the increased incidence of certain diseases in humans and animals.(12)(13) Many hazards and nuisances, such as fire, smoke, odors, and unsightliness, are also created by poor solid waste handling practices. The full appreciation of recreation area values by the public is often diminished by the disorder of accumulated solid wastes.

Among the elements to be considered in planning are:(14)

1. Collection of solid waste in durable, watertight, rust-resistant, nonabsorbent, and easily washable covered containers.

2. An adequate solid waste collection plan (number of containers, and frequency of collection) to prevent unsightliness and fly and rodent problems.

3. Disposal means for trash and garbage.

   a. by sanitary landfill
   b. by incineration
   c. by garbage grinding (to sewage system)

4. Prohibition of open burning other than campfires.

COMPATIBILITY OF RECREATION AND PUBLIC DRINKING WATER SUPPLY (15)(16)(17)

The competition among multiple uses of our land and water resources demands assessment of the compatibility of uses such as recreation and domestic water supply. There is no doubt that recreation comprises one of the major uses of water resources, representing major economic and social benefits. Domestic use is also a major benefit and may often be the most exacting use of the water resources. When various uses are not compatible and conflicts exist, compromise is necessary. Where multiple use calls for both water supply and recreation, the following factors should be considered:

1. Present physical, chemical, and bacteriological quality of the water resource.

2. Comparison of the probable degree of the contamination of the water resulting from recreational and other uses such as mining, logging, road building, and right of way maintenance; the resulting water quality should meet health guidelines and the applicable State or Federal standards for recreational and water supply use.

3. Degree of toxicological contamination and deterioration of water quality caused by wasted oils, motor fuels, pesticides, and other chemicals used to maintain and operate recreation facilities and equipment.

4. Control of taste, odor, and color producing algal growth.

5. Degree of water treatment required to handle anticipated pollution loads in order to produce water meeting the PHS Drinking Water Standards.

6. Provision for multiple elevation withdrawal points in the water supply intake to allow the advantage of planned withdrawal of the highest quality of water under the varying conditions of water quality in the reservoir.

7. Designation of a restricted area around the water supply intake in which recreational use is prohibited to prevent vandalism and to provide some holding time for the recreation water prior to its use for public water supply.

8. Complete clearance of the restricted area of vegetation, buildings, manure deposits, swamp debris, and other sources of contaminants.

9. Monitoring of the water quality on a regular basis.

These factors are normally considered in any drinking water supply development project. They are included here to remind planners that they should not be overlooked in multiple-use projects.

BODY CONTACT RECREATION WATER QUALITY

Limited biological, chemical, and physical quality guidelines are outlined below.(18) Where questions arise regarding the health aspects of water quality, local and State health authorities should be consulted. Reference should also be made to State Water Quality Standards and the water pollution control authorities responsible for the administration of such standards. Final judgment on the acceptability of the use of any water classified under these guidelines should also include consideration of the significance of the findings of a complete sanitary survey and continuous surveillance of possible hazards including a review of epidemiological data and appropriate safety considerations.

A. Biological:

The fecal coliform density should not exceed an arithmetic mean of 200/100 ml with a sampling frequency of 5 samples per 30-day period taken during peak recreational use. Not more than 10 percent of the samples' fecal coliform densities during any 30-day period should exceed 400/100 ml.

B. Chemical

The water should contain no chemical which could cause toxic reaction if ingested or irritation to the skin or eyes upon contact. The water's pH should be within the range 6.5-8.3.

C. Physical

The water's color should not exceed 15 standard units and its turbidity should not exceed 30 standard units.

SWIMMING POOLS AND OUTDOOR BATHING PLACES

Public health authorities have been concerned with sanitation and safety problems involving swimming and bathing for many years. While the problems of accidents and drownings are the most dramatic events relating to swimming, the communicable disease aspects must also be given attention.

The following factors should be considered:

1. Design, construction, and operation of proposed swimming pools in accordance with requirements of the health authority

having jurisdiction or in accordance with the standards outlined in the "Suggested Ordinance and Regulations Covering Public Swimming Pools"(19) and "Environmental Health Practice in Recreation Areas".

2. Acceptability to health authorities of the proposed water supply system to serve as a potable water source for the pool area.

3. Discharge of the swimming pool water through an air gap to the waste water receiver and recharge of the swimming pool through an air gap.

4. Proper design for "use loading".

5. Practice of continuous disinfection of pool water, where possible.

6. Routine examination of bacteriological samples taken from swimming pools and bathing places.

7. Decisions on the use of natural bathing areas based upon the results of chemical analyses, bacteriological examinations, and a sanitary survey of the proposed natural bathing area.

8. Elimination of possible gross animal pollution of the bathing area.

9. Evaluation of the effects of peak visitor days on water quality and recreational use.

BATHING LOAD FOR OUTDOOR POOLS AND BEACHES (WITHOUT DISINFECTION)

In a swimming pool whose water is derived from a public or other supply of drinking water quality, the presence of organisms of the coli-aerogenes group should be considered as an indication of pollution by fecal matter. The presence of such bacteria in natural bathing places, however, may be an indication of generally harmless soil bacteria. The portion of the total coliforms which is of fecal origin varies radically in surface waters. Routine bacteriological tests can detect the degree of the more hazardous fecal contamination through fecal coliform density determinations. Where outdoor beaches are used, the fecal contamination may be caused by sewage from boats, individual dwellings, hotels, factories or other establishments, public sewerage systems, refuse dumping, warm-blooded animals, and bathers themselves.

Where a beach will be dependent upon stream flow or lake circulation for cleansing and dilution, the amount of water flowing past the beach during the time of its use should be ascertained. Any small stagnant pool patronized by a number of bathers is certain to

show bacteriological pollution in considerable amounts unless disinfection is provided. While no specific amount of diluting water for outdoor beaches can be set on a scientific basis, a figure of 500 gallons per bather per day has been used in the past. The American Public Health Association publication, "Recommended Practice for Design, Equipment, and Operation of Swimming Pools and Other Public Bathing Places", (20) states "the total number of bathers using a fill and draw swimming pool shall not exceed one person for each 500 gallons of water in the pool between complete changes of pool water without disinfection".

The "Becker Formula" has been used in New York State(20) as a practical guide in determining necessary volumes of diluting water for outdoor beaches. This formula is $Q = 6.25T^2$ where Q = quantity of water per bather in gallons and T = replacement period in hours. As an example, if the water circulation is such that the beach volume will be replace in eight hours, then Q will be 400 gallons per bather; the number of bathers permitted in eight hours would be the total volume of the swimming area divided by 400.

Whether or not disinfection is employed, every effort should be made to eliminate all sources of sewage pollution on small streams or lakes used for bathing and careful sanitary surveys of the watershed are recommended. It is, of course, desirable that bathing be limited to clear bodies of water and that muddy bottoms which will cause turbid water be avoided.

RECREATION VEHICLE PARKING AREAS

The great increase in the number of recreation vehicles on the highways during the vacationing months is quite evident to the motoring public and reflects the increasing amount of leisure time and extra spending power being enjoyed by more people each year. It also points out the continuing need to expand recreation vehicle parking areas together with related facilities that meet standards of health and safety.

Considerations involving standards of health and safety are:

1. Design of parking facilities for both self-contained and non-self-contained recreation vehicles.

2. Provision of a sanitary station for the disposal of holding tank wastes. (For design, see "Environmental Health Practice in Recreation Areas".(1))

3. Design of recreation vehicle parking areas for overnight or destination use.

4. Availability of adequate water supply and satisfactory means of sewage disposal at each parking site.

5. Design of approach roads for trailer traffic.

6. Conformance of the spacing of recreation vehicles to the minimum 15 foot separation specified by the National Fire Protection Association.

7. Separation of at least 60 feet between the recreation water tank filling station and the sanitary station.

8. Special provisions for the disposal of sink wastes.

9. Development of detailed plans for solid waste disposal.

10. Convenience and adequacy of service buildings for their anticipated use.

11. Provision of electrical service by underground cable.

12. Submission of detailed plans and specifications of the recreation vehicle parking areas to the health authority having jurisdiction for review and approval.

BOATING

The boating industry reported in 1962 that there are more than eight million pleasure boats being used for recreation in the waters of the United States and the trend is increasing upward. More and more of these boats are being equipped with a galley and toilet facilities. Sewage, galley wastes, and other debris are therefore being discharged into our watercourses threatening to damage the recreational values of swimming, fishing, and other aquatic sports. The dredging of boat basins and the construction of small craft harbors, marinas, boat launching ramps, and docking floats are but a few of the projects being constructed or planned for recreation areas. Such new developments which attract and serve boating enthusiasts may create water pollution and related health problems of concern to public health and recreation authorities.

For this reason it is most important that the planning of such developments consider the environmental health aspects involved such as:

1. Inclusion of adequate separate facilities for collection and disposal of sewage, waste oils and fuels, and solid wastes accumulated on boats in the planning and design of proposed marinas.

2. Location of a permanent comfort station with sanitary facilities for both sexes near the piers.

3. Provision of a water-carried sewage disposal system including adequate treatment.

4. Provision of land disposal of wastes from floating facilities.

5. Provisions to eliminate waste and spillage during storage and dispensing of gasoline from floating facilities.

6. Regulation of construction and use of boats with marine toilets.

7. Inclusion of good solid waste disposal practice.

8. Establishment of restricted areas around water supply intakes.

9. Boats should meet safety requirements recommended by the U.S. Coast Guard and regulations should be established to control health and accident hazards associated with boating.

10. Full separation of boating and swimming areas.

11. Adequate parking facilities for automobiles and trailers.

FISH CLEANING FACILITIES

Fishing is an activity many visitors enjoy while visiting recreation areas, especially where natural reproduction and stocking of local waters is accomplished. Where fishing is productive, consideration should be given to the installation of fish cleaning facilities near boat docking and launching areas. These facilities are essential to control nuisances, odor, and pollution from the indiscriminate cleaning of fish and disposal of the resulting wastes into lakes, reservoirs, and along shorelines.

In planning these facilities, consideration should be given to the following factors:

1. Screening or full enclosure of the facility.

2. Provision of tables having impervious, nonabsorbent surfaces sloping to central drains or of adequately maintained wood tables.

3. Provision of potable water under pressure adequately protected against back-flow.

4. Provision of adequate disposal of collected wastes and maintenance of the facility in a clean condition.

INSECT AND RODENT CONTROL (See also Chapter V)

Several groups of arthropods and rodents may create serious public health and nuisance problems at recreation areas. These include species that are vectors of human disease organisms or which serve as reservoirs of these organisms or otherwise interfere with man's health, welfare, and comfort. A number of aquatic insects may be encountered at recreation areas located along the shore of impoundments. Mosquitoes are undoubtedly the most important of these insects, since several species serve as vectors of encephalitis and malaria, and others create public health problems because of their vicious biting habits.(21) Other groups of aquatic insects such as deer flies, horseflies, black flies, and biting midges are vicious biters of man and sometimes are involved in transmission of disease. In addition to the aquatic insects, people who visit water-related and other recreation areas are often exposed to terrestrial arthropods such as ticks, mites, fleas, and flies and rodents including ground squirrels, rats, and mice.(22)(23) The public health importance of these arthropods and rodents involves a number of human diseases including Rocky Mountain spotted fever, Colorado tick fever, tularemia, relapsing fever, tick paralysis, typhus, plague, bacillary dysentery, and typhoid fever. Irritation, discomfort, and annoyance caused by bites of the arthropods can seriously reduce the use of an otherwise attractive recreation area. Thus it becomes most important that measures be taken to eliminate or reduce such insect populations. State health authorities should be asked for pre-construction surveys and technical assistance in preparing control programs based on the following principles:

1. Delineation of mosquito production sites.

2. Implementation of mosquito control practices in preparation of the reservoir basin prior to impoundage.

3. Utilization of naturalistic and source reduction measures.

4. Planning for maintenance practices to control mosquito production within flight range of recreational and inhabited areas.

State and Federal health agencies will also provide technical information concerning:

1. Steps to be taken to control terrestrial arthropods and rodents.

2. Hazards to humans and animals posed by proposed chemical control measures against insects and rodents.

CAMPGROUNDS, PLAYGROUNDS, AND PICNIC AREAS

Camping is often a necessary part of any outdoor recreation outing that extends beyond one day. Many vacationers stay in motels and hotels; however, tents and recreation vehicles have loomed larger and larger on the recreation scene in recent years. Camping is increasing at a faster rate than the provision of sites and facilities for camping. Increases in camping will most certainly accompany increases in travel, for camping makes it possible for families to enjoy weekends and vacations economically far from home.

When resources are developed for boating, fishing, hunting, and related activities, adequate facilities for camping also should be provided. Studies of participation in outdoor recreation have shown that substantial numbers of campers prefer remote areas, while many others prefer camping in an area where they can visit with other campers.(24) Consequently, both types of camping areas are needed, with proper consideration given for environmental health factors relating to this mode of recreation.

Factors of importance are:

1. Provision of level and well-drained tent areas.

2. Plans for regular maintenance of the grounds (cleaned, mowed, and poisonous plants and hazards removed)

3. Remoteness of playgrounds from traffic areas, hazardous topographic features, and hazardous land uses.

4. Convenient location of water supply hydrants and comfort stations in the area.

5. Camping units should be located on one-way loop roads and/or cul-de-sacs.

STABLE SANITATION

The primary environmental health concern associated with the use of horses is the stabling of these animals and related manure disposal. Accumulations of such wastes afford breeding places for flies and unless controlled, will invariably produce large numbers of flies. Public health officials recognize that flies constitute a public health hazard and that the abatement of fly populations is essential to the control of certain communicable diseases.

These principles should be applies:

1. Stables convenient to recreation areas, but located to minimize potential odor and nuisance problems.

2. Provision of water outlets for hosing down feed and tack rooms, adequately protected against back-flow.

3. Provision of adequate water supply and drainage lines.

4. Implementation of insect and rodent control practices.

5. Handling and disposal practices for manure that prevent the breeding of flies.

CONCLUSION

If these factors or principles have been considered and properly resolved, adequate attention has been given to health considerations in the project development. However, if they have not been considered and resolved, the health and well-being of recreationists will not only be endangered but the project will fall short of its optimal development and use. Additional funds for sanitary and related facilities will often be justified in achieving an optimal result from the expenditure of the basic development funds. Health agencies at the local, State, and Federal level can be of considerable assistance in providing the technical direction necessary to insure the inclusion of a healthful environment in the development of water resources.

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CHAPTER V - VECTOR CONTROL

Health Guidelines for Vector Control are intended for the use of public health agencies, water resource construction and operation agencies. The Guidelines should assist in the study and evaluation of vector control problems and in the prevention and control of disease vectors and pests which may be associated with water and related land resources.

The Guidelines may be broken down into two categories:

1. Principles and Practices for the Prevention and Control of Vector Problems.

2. Field Survey and Epidemiological Surveillance.

Major vectors considered include mosquitoes from the water resources and terrestrial arthropods and rodents from the related land resource.

The major disease transmitted by mosquitoes are malaria, yellow fever, dengue, encephalitis, and filariasis. Control programs and climate have now reduced malaria, yellow fever, dengue and filariasis to minor or historical importance in the United States. Five types of encephalitis continue to occur in epidemic form in many parts of this country, however, and are the most important mosquito-borne diseases in the United States today. From 1956-1968, 3,121 cases of human encephalitis were identified as mosquite-borne(1), with the incidence from various strains as follows:

Western Encephalitis	665 cases
Eastern Encephalitis	92 cases
St. Louis Encephalitis	2127 cases
California Encephalitis (Not identified by most laboratories prior to 1964)	236 cases
Venezuelan Encephalitis	1 case
Total	3,121 cases

The maps in Figure 1 illustrate the relative occurrence of the major types of encephalitis in the United States.

At present, ticks are known to transmit five groups of deadly diseases: rickettsial, such as spotted fever; bacterial, such as tularemia; spirochetal, such as relapsing fevers; viral, such as Colorado tick fever; and protozoal, such as Texas cattle fever. They also produce a toxic paralysis. Tick-transmitted diseases have occurred primarily in the South Atlantic, Appalachian, and Western States. Lowest incidences occur in New England, New York, the West

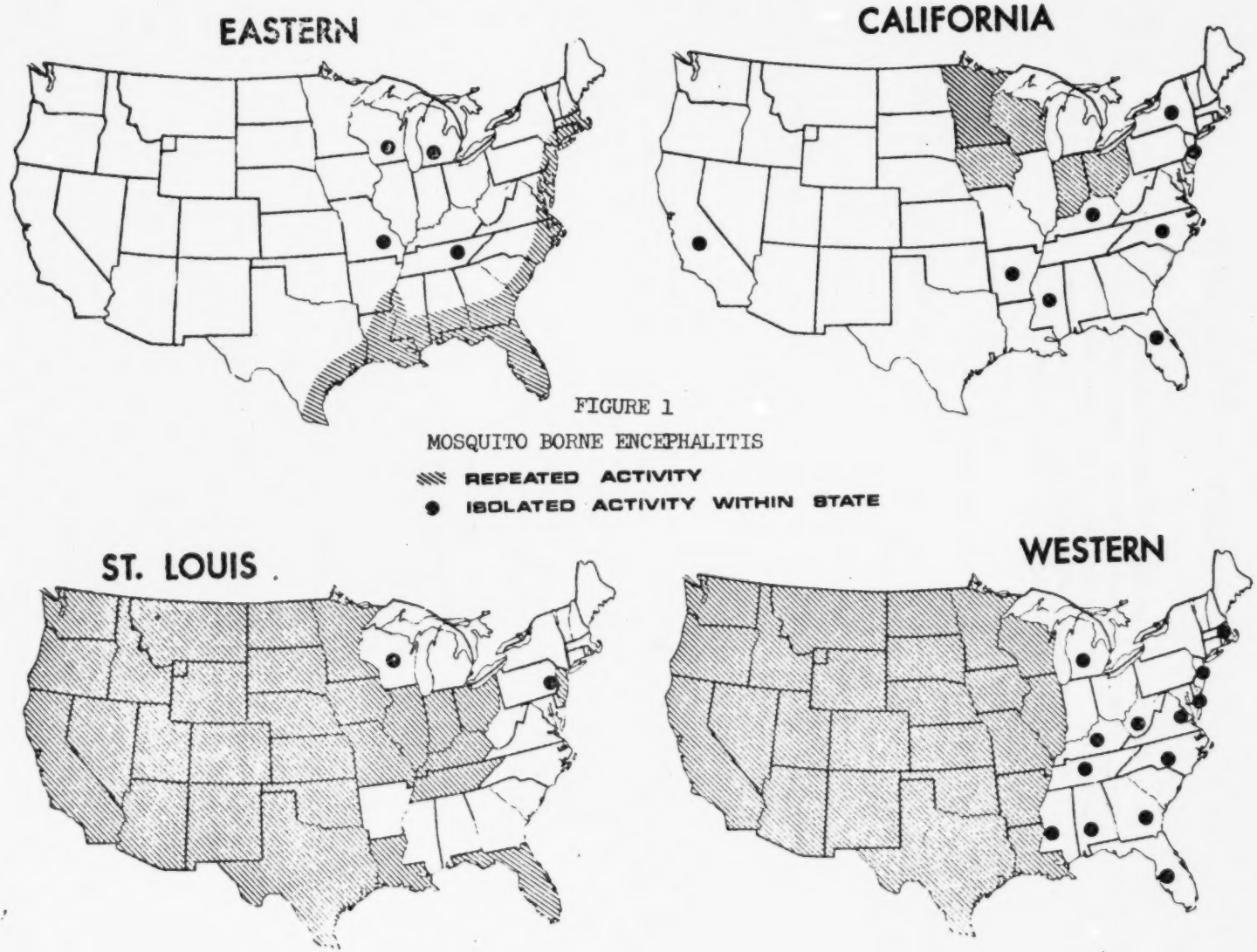

FIGURE 1

MOSQUITO BORNE ENCEPHALITIS

Central states, Hawaii, and Alaska. Since ticks are so widespread, however, the hazard from them should be considered in all regions.

PRACTICES FOR THE PREVENTION AND CONTROL OF VECTOR PROBLEMS

In the prevention and control of vector problems, special emphasis must be placed upon the prevention of physical conditions which may result in increased vector populations and upon the establishment of physical conditions which will minimize or eliminate existing vector problems; attention must also be given to factors such as the maintenance of basic sanitation standards, programs for the application of insecticides, location of habitable areas away from potential mosquito production areas, and so forth. The following principles and practices for prevention and control of vector problems should be followed in the planning, design, construction, operation, and maintenance of water and related land resource projects.

A. Impoundments

Practices leading to the prevention and source reduction of mosquito and other aquatic insect breeding sites include the following:

1. All borrow pits and other potential ponding areas associated with construction of the dam, relocation of highways or roads, etc., which are located above maximum pool level should be made self-draining.

2. Prior to impoundage, the reservoir basin should be prepared as follows:

   a. The normal summer fluctuation zone of the permanent pool should be selectively cleared except for isolated trees and sparse vegetation along abrupt shorelines which will be exposed to wave action.

   b. Dense stands of timber rooted below the normal summer minimum pool level but extending above that level should be selectively cleared.

   c. Borrow pits, depressions, marshes, and sloughs which will be flooded by the reservoir at maximum pool level and which would retain water at lower pool levels should be provided with drains to insure complete drainage with fluctuation of water levels.

   d. If the summer fluctuation zone of the permanent pool is limited to a few feet, consideration should be given to "building out" mosquito-producing areas located within flight range of population groups or recreation areas

through the use of measures such as deepening and/or filling. This would minimize the need for repetitious measures for controlling vegetation and mosquito production.

e. If releases of water during portions of the year coincident with mosquito breeding season are quite small, consideration should be given to provision of low flow channels in drainage systems below the dams.

3. After impoundage, the following maintenance measures should be carried out in all potential mosquito-producing areas located within flight range of human population groups or recreation areas frequented by significant numbers of persons.

   a. All dense vegetation should be removed periodically from flat, protected areas within the normal summer fluctuation zone of the permanent pool.

   b. Vegetation, debris, and flotage should be removed periodically from all drains to insure free flows.

4. Water level management to minimize conditions favorable for mosquito production should be used to the maximum degree permitted by the primary purposes of the reservoir. This will minimize the need for repetitious measures for controlling vegetation and mosquito production.

5. As a general principle, waterside recreation areas, particularly those which have facilities for overnight human occupancy, should be located along sections of the reservoir which have a low production potential for mosquitoes and other aquatic insects of public health importance.

6. Biological control measures such as maintaining populations of mosquito larva predators should be exercised as needed.

B. Recreational Areas

1. Proper storage, collection, and disposal of solid wastes should be practiced in order to prevent and control flies, wasps, other noxious insects, rats, wild rodents, and other small mammals. Disposal of containers such as tin cans which would hold water reduces the breeding of mosquitoes within recreation areas.

2. All buildings should be rodent-proofed at recreation areas where rodents which may create public health hazards are prevalent.

3. Debris, rubbish, and other materials which may serve as harborage for rodents and other small animals should be removed periodically. At least twice a week removal of garbage is necessary to minimize fly production during the summer months. Where pit privies are provided, they should be fly tight and constructed to minimize the possibility of rodent harborage. Where possible, such unsatisfactory facilities should be replaced with modern water carriage sewage disposal systems.

4. Brush and weeds along paths, trails, roadways, and other areas frequently used by visitors should be treated with herbicides or removed in order to reduce the likelihood of tick and chigger infestations; however, herbicides should be used only in accordance with recommendations of appropriate Federal and State agencies.

5. Tree holes which may hold water should be filled with sand or grout to eiminate breeding places for mosquitoes and biting gnats.

6. Proper sewage and solid waste disposal is essential to prevent vector problems.

C. Waterfowl Refuges

1. Whenever possible, waterfowl habitat developments should be constructed so as to minimize mosquito problems.

2. Waterfowl areas which are to be flooded during the mosquito season should be diked or otherwise prepared with steep shorelines to preclude shallow water areas favorable for mosquito production. Banks should not be made so steep as to impair stability.

3. Provision should be made for water level management in waterfowl areas which will minimize mosquito production. This recommendation is particularly applicable to shallow areas used to provide establishment of food producing vegetation.

D. Irrigation

1. Project Conveyance and Distribution Systems

a. Lining or other satisfactory seepage control measures should be provided for all sections of canals and laterals located in porous soils where excessive leakage would result in waterlogged areas, seeps, and ponds.

b. Drains should be installed to prevent ponding of excess irrigation water and natural runoff along the upper side of canals and laterals. All drainage crossing or inlet structures should be placed on grade to prevent ponding.

c. Borrow areas should be made self-draining to prevent the retention of ponded water.

d. Where possible, provision should be made to prevent idle turnouts and other hydraulic structures from retaining residual water.

e. Effective measures should be provided to prevent ponding of leakage from water control structures.

f. Every effort should be made to establish delivery schedules which will provide farmers with adequate but not excessive amounts of water at proper intervals to insure efficient irrigation of the crops concerned.

g. Where feasible, pipes should be used rather than open channels.

h. Vegetation and debris which would retard normal flows should be periodically removed from conveyance channels, water control structures and drains.

2. Project Drainage Systems

a. Trunk drainage systems should be installed to insure complete removal and proper disposal of excess irrigation water, natural runoff, and seepage from both irrigable and nonirrigable lands affected by the distribution and use of irrigation water on the project.

b. Drainage ditches should be designed, constructed, and maintained so as to minimize ponding in the channels and to insure free flows at all times.

c. Provision should be made to prevent water from ponding behind spoil banks.

d. Underdrains, culverts, inlets, etc., should be placed on grade to prevent ponding.

3. Irrigated Farms

a. The sponsoring agency and other organizations concerned with irrigation agriculture or mosquito control should

encourage irrigation farmers to use the following irrigation and drainage practices which will prevent or minimize mosquito sources:

(1) The farm supply system, drainage system, and field layouts should be properly fitted to the topography, soil, water supply, crops to be grown, and irrigation methods to be used.

(2) All surface irrigated fields should be properly leveled or graded to provide for efficient water application and removal of excess water without ponding.

(3) An adequate drainage system should be provided for removal of excess irrigation water from all portions of the farm.

(4) Irrigation methods should be used which will provide optimum irrigation efficiencies.

(5) Application of irrigation water should be limited to the amount required to fill the crop root zone plus water to cover unavoidable losses and excess water needed to prevent upward movement of salts.

(6) Where feasible, sprinkler systems should be employed.

E. Ponds

1. The pond basins should be cleared of trees, brush, and other dense vegetation prior to impoundage.

2. Ponds should be constructed with steep banks to discourage growth of vegetation. Banks should not be made so steep as to impair stability.

3. All dense vegetation should be removed periodically from shallow water areas.

4. A minimum depth of 2 feet should be maintained.

F. Channel Improvements and Drainage

1. Borrow areas resulting from construction of the project should be made self-draining.

2. Material excavated from channels should be disposed of in such a way that it will not cause ponding of water.

3. Adequate drains should be installed to prevent ponding of water on berms or behind spoil banks, levees, and dikes.

4. Drainage ditches should be designed, constructed, and maintained to concentrate low flows and reduce silt deposition and subsequent ponding, thereby insuring free flows at all times.

5. Underdrains, culverts, inlets, etc., should be place on grade to prevent ponding.

6. Collection sumps should be constructed with steep side slopes, and any emergent vegetation should be removed periodically.

7. Sections of natural channels that are cut off or bypassed by new channels should be filled or provided with adequate drains.

8. Interior drainage facilities should be well maintained to avoid excessive ponding.

9. The use of biological control measures such as stocking with the mosquitofish or top minnows, such as Gambusia affinis, should be used where feasible.

G. Waterways, Terraces, Floodways, Diversion Channels, and Drainage Ditches

1. Waterways, terraces, floodways, diversion channels, and drainage ditches should be designed, constructed, and maintained to prevent the retention of ponded water or the creation of ponded areas which would be suitable for mosquito production.

2. Biological control measures should be used where feasible.

H. Supplemental Chemical Control Measures

1. In situations where adequate vector control is not obtained through prevention and source reduction measures, provision should be made for supplemental use of insecticides and rodenticides to achieve the desired level of control. The use of such chemicals should be closely regulated to prevent the possibility of water pollution resulting from such activity.

FIELD SURVEY AND EPIDEMIOLOGICAL SURVEILLANCE

In order to insure that good principles and practices are actually

being implemented, that vectors are being controlled, and that disease and nuisance are being prevented, arrangements should be made for routine field survey and for epidemiological surveillance. The routine field surveys should include not only inspections for implementation of physical measures, but also inspections for the presence of adult and larval mosquitoes and other vectors. Regular information on vector populations or disease occurence is essential in guiding control programs or instituting new programs to cope with existing vector problems as well as unforeseen or emergency situations.

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CHAPTER VI - SOLID WASTE MANAGEMENT

The management of solid wastes is a growing national problem and must meet limitations related to public health, environmental protection, and economic resource recovery. Local and State agencies responsible and interested in public health, environmental protection, solid waste management, water pollution, and water resources development should be consulted regarding such limitations on a case-by-case basis.

Proper solid waste management will improve the safety and quality of the environment:

1. By eliminating harborage and food supply for rats, flies, mosquitoes, and other disease vectors or nuisances.

2. By controlling air pollution through the elimination of open burning or, in the case of incineration, more efficient combustion. Odors, fly ash, and smoke are controlled through proper combustion control design and operation.

3. By safeguarding against surface and ground water pollution associated with improperly disposed solid waste.

4. By reducing accident and fire hazards through the elimination of open burning or dumping of solid waste.

5. By making solid waste disposal mechanisms aesthetically acceptable.

Solid waste management and its potential effects should be considered in water resources development projects, paticularly where recreation and water quality are of importance. Harborage and food supply for insect and animal disease vectors or nuisances, surface and ground water pollution, accident and fire hazards and aesthetic insult often result from improper storage or disposal of solid wastes.

ACCUMULATION AND STORAGE

Solid waste management begins with the provision of an efficient mechanism for the storage of waste generated by individuals at the sites of interest. Normally such a mechanism is simply the provision of insect and rodent proof containers of sufficient volume to hold the maximum amount of waste generated between collections.

COLLECTION

Solid wastes should be collected at appropriate intervals to prevent fly and insect breeding and the occurrence of odor problems. The

collection frequency should be adjusted in accordance with rates of accumulation and climatologic and geographic factors. Plans should provide not only for the efficient collection of the solid waste, but also for its effective and economic disposal. (1)

DISPOSAL

After accumulation and collection, treatment and disposal of the solid waste must be accomplished. Acceptable disposal occurs when no significant deterioration of the environment results from disposal operations. Modern practices for disposal are discussed as follows:

Sanitary Landfill

Sanitary landfill is an engineered method in which solid wastes are disposed by spreading them in thin layers, compacting them to the smallest practical volume and covering them with earth each day in a manner that minimizes environmental pollution.(2) The term "sanitary landfill" is sometimes mistakenly associated with open dumping. Dumps, however, are a source of many environmental insults.

Advantages of the sanitary landfill are as follows:

1. Where land is available, a sanitary landfill is usually the most economical method of solid waste disposal.

2. The initial investment is low compared with other disposal methods.

3. A sanitary landfill is a complete or final disposal method as compared to incineration and composting which require additional treatment or disposal operations for residue, quenching water, unusable materials, etc.

4. A sanitary landfill can be put into operation within a short period of time.

5. A sanitary landfill can receive all types of solid wastes, eliminating the necessity of separate collections.

6. A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little additional personnel and equipment.

7. Submarginal land may be reclaimed for use as parking lots, playgrounds, golf courses, airports, etc.

Disadvantages of the sanitary landfill are as follows:

1. In highly populated areas, suitable land may not be available within economical hauling distance.

2. Proper sanitary landfill standards must be adhered to daily or the operation may result in an open dump.

3. Sanitary landfills located in residential areas can result in extreme public opposition.

4. A completed landfill will settle and require periodic maintenance.

5. Special design and construction must be utilized for buildings constructed on completed landfill because of the settlement factor.

6. Methane, an explosive gas, and other gases produced from the decomposition of the wastes may become a hazard or nuisance problem and interfere with the use of the completed landfill.

Incineration

Properly designed incinerators can be used for the treatment of solid wastes. It should be noted that the incinerator does not eliminate the need for a sanitary landfill; it simply reduces the volume of the material requiring eventual disposal.

Advantages:

1. Reduces the amount of solid waste requiring final disposal.

2. Allows more efficient collection practices in some situations by reducing haul distances when the incinerator has a central location near the sources of waste.

Disadvantages:

1. Capital costs and operating costs are higher than for the sanitary landfill.

2. Requires full time operators to assure acceptable operation.

WATER RESOURCE ASPECTS OF SOLID WASTE DISPOSAL

Recreation Areas

Recreation areas and their supporting facilities may be expected

to generate significant amounts of solid waste and to present varying problems of solid waste management. Solid waste management for recreation areas is discussed in Chapter IV.

Reservoir Planning

Before impoundment, a survey should be made to locate solid waste disposal sites that will be inundated. This survey should be part of a general assessment of pollution sources, levels, and potential. If it is determined that these sites could cause a significant pollution problem, the objectionable material should be removed or the location of the reservoir altered to avoid the solid waste site.

The filling of a reservoir represents a change in hydrologic conditions which will raise the nearby groundwater table. If the higher groundwater table intrudes upon a solid waste disposal site, pollution could result. Further investigation and corrective and/or protective measures should be taken accordingly.

Water Quality

Most solid waste is ultimately placed in contact with the ground, permitting possible contact with both ground and surface water which could cause subsequent impairment of water quality.(3) Investigations into the subject of contamination of water by solid waste disposal have established the fact that the physical, biological, and/or chemical quality of surface and ground water may be affected by nearby solid waste disposal sites.(4) Turbidity is normally a problem only in the immediate vicinity of the disposal site. Taste and odor may be particularly affected by hydrogen sulfide absorbed by water passing through or over anaerobically decomposing wastes. Although color may be present, it is normally removed by natural purification processes.

Bacterial contamination within and close to a disposal site may be very high. For sandy or granular aquifers, bacterial contamination does not normally persist at depths greater than seven feet below a disposal site and seldom persists in ground water in the direction of flow for more than 50 yards.(5) In limestone, lava rock, most sandstones, granite, and other crystalline rocks, however, water travels through discrete openings such as tubes, parting planes between layers, or fissures produced by earth movements. No filtering action occurs in moving through these openings and contamination can travel long distances modified only by dilution.

The mineral and organic substances in solid wastes are present in quantities capable of causing gross contamination of surface and ground water supplies. Soluble inorganics such as chlorides, ammonium hydroxide, and ammonium salts are not rapidly removed by natural means.

Decomposition of organic matter produces carbon dioxide, water, methane, ammonia, and hydrogen sulfide. The increase in hardness caused by carbon dioxide and the increase in nitrate content resulting from the oxidation of ammonia are among the most significant effects on water quality. The highly soluble carbon dioxide also forms a weak acid which can dissolve metals and other substances to produce undesirable contaminants.

Mechanism of Contamination

The major processes by which contaminants are produced or introduced into ground and surface water, other than direct dumping, are infiltration and percolation, solid waste decomposition processes, gas production and movement, leaching and ground water travel, and direct runoff.(6) Infiltration and percolation of rainfall, runoff, irrigation, and flood water can produce contaminating leachates. Decompostion of waste constituents by chemical and bacterial action depends upon time, composition, availability of oxygen, temperature, moisture, salinity, and other factors; and makes many chemical products available as contaminants. Aerobic decomposition produces a rise in temperature and the primary products, carbon dioxide and water. Anaerobic decomposition produces ammonia and methane as the primary products accompanied by a rise in temperature.

For leaching and ground water travel to occur, three conditions must be satisfied:

1. The disposal site must be over, adjacent to, or in an acquifer.

2. The fill or a portion of it must be saturated.

3. Leached fluids must be produced which have access to an acquifer.

The possibility of contamination from a solid waste disposal site will depend upon factors including the composition and quantity of waste involved, the site's physical environment, the operation of the site, and the volume and original quality of the water.

SANITARY LANDFILL SITE SELECTION AND OPERATION

The possibility that a landfill will pollute ground and surface waters in the area of the fill must be considered. Various substances may be present in solid wastes which are capable of causing contamination of surface and ground water supplies.

A competent sanitary engineer should be consulted to evaluate the water pollution potential associated with disposal sites and the protective measures that may be necessary. The services of a soil scientist or a groundwater geologist may also be useful.

To minimize the potential of surface and/or groundwater contamination, the following guidelines should be adhered to:

1. Solid waste should never be buried in direct contact with a groundwater or surface water supply; burial areas should also be located so as to minimize any contamination of waters which may serve as sources for municipal or drinking water supplies.

2. Surface water passing over or through a disposal site should be minimized by proper drainage. Finished sites should be covered and graded to control the flow of runoff across the fill area.

3. Water should not be intentionally added to a solid wastes disposal site, except to extinguish fires.

4. Site selection should be based upon evaluation of the entire physical environment surrounding proposed sites.

5. Recommended procedures for the operation and maintenance of a sanitary landfill, using sound engineering practices and judgment, should be implemented.(2)

6. In the planning and implementation of solid waste disposal, consultation should be sought from local, State, and Federal agencies responsible for and interested in environmental protection, public health, solid waste management, water pollution control, and water resources development in order to minimize the hazard of water contamination and to institute corrective engineering measures where needed to minimize water contamination.

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CHAPTER VII - RADIOLOGICAL HEALTH

This guideline is directed to a general discussion of radiological health aspects of water and related land resources in the United States. The problem areas, sources, mechanisms of exposure, and surveillance, should be considered for the watershed of any project including water supply, irrigation, or recreation as project purposes. In each of the areas discussed, more detailed information is readily available, in the indicated references.

SOURCES OF RADIOACTIVE CONTAMINATION

The sources of radioactive water contamination are numerous and include hospitals, industrial laboratories, nuclear reactors, and fuel fabrication and reprocessing plants. Hospitals and certain industrial and research laboratories dispose of low levels of water-borne radionuclides, used in basic research and in treatment of patients, by flushing to sanitary sewers. Radioactive wastes can also occur at these facilities through leakage from continuous processing systems. Considering the diversity of radiological medical and research applications, almost any radionuclide might occur in the liquid wastes of these facilities. The use of isotopes in medicine and research, however, is not normally great enough in any given area to present a hazard to individuals through contamination of the environment.

The principal types of reactors currently operating in the United States are electric power reactors, production reactors, and research reactors. Of these three types, power reactors will present the greatest problems of radioactive liquid waste disposal in the future due to the increased use of nuclear power for generation of electricity. The data shown in Table I indicates that nuclear power will move from its position of supplying approximately 6% of the electrical energy requirements in 1970 to around 30% in 1980. Production of liquid radioactive wastes can be expected to increase with this increase in nuclear power generation. However, due to the management of the radioactive waste treatment system and development of new technology, the release of radioactive material to the environment will not increase proportionally but will be maintained at the lowest practicable level.

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TABLE I

Projected Energy Sources for Electric Power

SOURCE	1970		1975		1980	
	MW(e)x10^3	% of Total	MW(e) x 10^3	% of Total	MW(e)x10^3	% of Total
Nuclear	20	6	69	16	160	30
Water	46	14	65	15	70	13
Oil	23	7	13	3	16	3
Gas	69	21	89	21	75	14
Coal	172	52	194	45	214	40
TOTAL	330	100	430	100	535	100

The types of nuclear power plants presently being designed and operated in the United States are pressurized water reactors (PWR) and boiling water reactors (BWR). Both types of facilities have been designed to release relatively low levels of liquid wastes during normal operation. Low level liquid wastes are usually released directly to the condenser cooling water discharge canal where they are diluted (by a factor of 10^4 to 10^6) (1) with the condenser cooling water to acceptable environmental levels. Where liquid wastes generated by reactors utilizing cooling towers are released to the blow down of the cooling towers, available dilution is much smaller than for facilities not using cooling towers. Provisions are made for removing radioactive contaminants contained in high and intermediate level liquid wastes by one or more of the methods given below:

1. Storage to allow decay of relatively short-lived isotopes.
2. Filtration to remove particulate activity.
3. Ion-exchange to remove dissolved activity.
4. Distillation to reduce volume of wastes to be stored.

These treatment methods are commonly applied throughout the reactor industry and may also be applied at any facility where radioactive liquid wastes are generated and discharged.

Uranium milling can contribute to the natural uranium activity of streams used for disposal of wastes from the milling process. The concentration of uranium in such streams should be carefully monitored and controlled in areas where uranium mining is prevalent.

With the projected increase in reactor use, reactor fuel reprocessing plants will become more important as potentailly hazardous sources of contamination. Such plants have a greater potential for contaminated waste production than reactors, but will probably number less than 10 in the United States by 1980.

MECHANISMS OF HUMAN EXPOSURE

Once water becomes contaminated with radioactive pollutants, the following pathways for population exposure should be considered:

1. Human consumption of contaminated drinking water.
2. Use of contaminated water in recreational sports.
3. Concentration of pollutants in edible aquatic biota, especially fish and shellfish.
4. Irrigation and subsequent concentration of radionuclides by food crops.
5. Contamination of various foods by use of contaminated water for processing.
6. Settling of radioactivity and resuspension during periods of flooding. Radioactivity can also be absorbed by particulate deposits and then desorbed upon changes in thermal, chemical, or biological character of the stream.

The most likely occurrence of hazardous exposure would be through drinking of contaminated water and from consumption of contaminated food. Water resource development projects will be most concerned when water supply, irrigation, and/or recreation are included as project purposes. After an unintended release of radioactive materials into a waterway, two principal factors must be considered in controlling exposure from drinking water:

1. Minimum travel time from point of release to water intake - determines time available after a release of pollutants during which authorities may discontinue intake of raw water in order to avoid use of the polluted waters or to prepare treatment processes to remove the pollutants.

2. Water plant storage capacity and population usage rate-determines length of time water intake may be stopped by authorities without discontinuing water service.

3. Water plant contamination removal efficiency - determines amount of contamination which can be removed by treatment. This

efficiency may vary for different pollutants.

4. Decay time during treatment and storage - accounts for radioactive decay during water treatment and storage before use.

5. Dilution, both in-stream and in the treatment plant - determines the concentration which may reach the individual customer.

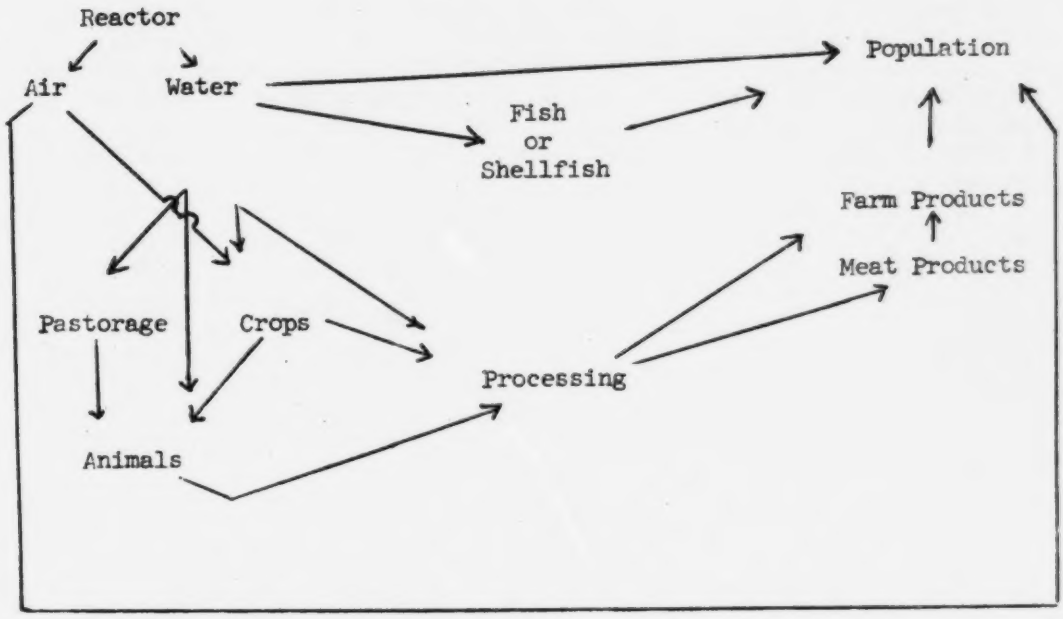
In protecting the population from consumption of radiologically contaminated food, the efficiency of food processing in removal of the contaminant and the decay time between contamination and possible human consumption are important factors. Where food becomes grossly contaminated, removal of the affected foods from the food supply is an obvious and effective method for population exposure control.

Radioactive water contamination can also affect the industrial use of water at a particular location. Any industry which manufactures a product which is affected by radiation such as film manufacturers will be concerned about the concentration of radioactivity in their process water.

Radioactive contamination of land usually occurs via deposition of airborne contaminants or through use of contaminated water for crop irrigation. The pathways for exposures of humans to radioactive contaminants emitted by a source including exposure through the human food chain are shown in Figure 1.(2) The hazard presented in any case is highly dependent on the contaminating radionuclide. Land contamination can create a more serious long-term exposure problem than water contamination because very little dispersion or movement occurs following deposition and fixation in the soil.

The various pathways for population exposure discussed above demonstrates the importance of zoning in areas where facilities discharging radioactive contaminants are located. During the initial evaluation of the site for a facility emitting radioactive substances a certain area of restricted land development is established around the facility. In many cases, it would be possible for population or industrial growth in the area to progress to the point where the criteria established by the original site evaluation will no longer be acceptable due to the larger populations which would be exposed to radiation accidents. Certain zoning restrictions may therefore be required to prevent unacceptable population, commercial, or industrial growth in close proximity to the facility.

Figure 1



Pathways for Human Exposure to
Radioactive Substances

SURVEILLANCE AND CONTROL OF RADIOACTIVE CONTAMINATION

The surveillance and control program proposed for a facility releasing radioactive liquid wastes to surrounding waters depends upon the facility type and the levels of activity discharged relative to permissible levels. There are two published guides currently used for specifying permissible activity levels in water. The first is the "Public Health Service Drinking Water Standards - 1962 (3). The "Radioactivity" section of the drinking water standards discusses, in general, surveillance of drinking water sources and levels of radium-226 and strontium-90 at which various surveillance and control actions are necessary. The second guide is Title 10, Part 20 of the Code of Federal Regulations(4) entitled "Standards for Protection Against Radiation." This guide sets forth "maximum permissible concentrations" (MPC) in air and water for most radioactive isotopes which would be discharged to the air and water environment from nuclear installations.

The prime objectives of environmental surveillance programs for facilities releasing radioactive wastes are:

1. to verify the adequacy of source control.

2. to provide data to estimate population exposure.

3. to provide a source of data for public information.

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This program should include emergency planning designed for the purpose of detecting individual releases in time to take protective action. If environmental monitoring is conducted for the purpose of initiating protective action, daily or continuous sampling with rapid analysis and alarm is necessary, a requirement most routine environmental monitoring programs cannot meet. Protective actions can appreciably reduce the dose received if initiated quickly. The signal for these actions should come immediately from the facility in question, not several days or weeks later from environmental sampling. For this reason it is essential that adequate source monitoring and control be in effect to immediately detect significant non-routine releases of radioactivity, and that agencies responsible for public health be promptly notified so they can initiate necessary sampling programs and protective actions if needed. A special preplanned emergency surveillance system is required to adequately assess the public health hazard in the event of a major accidental release of radioactivity to the off-site area.

The surveillance guidance discussed in the remainder of the section pertains to the operation of nuclear installations under conditions of normal discharging of radioactive liquid wastes. The complexity of a surveillance plan at a particular installation will depend on the types and levels of radioactive releases.

A routine program to meet the environmental surveillance objective given above has been described in detain for a nuclear reactor plant in several references.(5)(6)(7) These references include lists of recommended sample types, frequencies, and radionuclides of principal interest. A typical program for the water environment is outlined in Table 2.

The Federal government conducts a comprehensive nationwide environmental surveillance program in the form of its national surveillance networks.(9) Information from these networks is used to estimate public exposure and doses relatable to environmental radioactivity. The surveillance system is designed to be responsive to changes in radioactivity levels in the environment. The current surveillance activities include the collection and analysis of airborne particulates, water, milk, total diets, human bones and organs, and special samples relating to human body burdens. Many States operate similar statewide networks that are coordinated with the Federal network systems. In addition, environmental surveillance programs are conducted in the vicinity of operating nuclear facilities by the operator and health agencies. With such a system of National, State, and facility surveillance programs in operation, the long-term trends of environmental radioactivity resulting from the nuclear industry can be well documented. In addition, special surveillance systems have been established which can be activated in the event of a facility accident and which will indicate whether levels of radioactive contaminants exceed Federal Radiation Council guidelines for protective action to control population exposure. (10)(11)

TABLE 2

TYPICAL WATER AND LAND SURVEILLANCE PROGRAM

FOR NUCLEAR POWER PLANT(8)

Indices	Recommended Surveillance Program		
	Relative Frequency	Analysis	Sampling Locations
Surface Water Receiving Waters of the Facility	Continuous composite or weekly grab	Gross beta and gamma scans. Periodic beta scintillation analysis for ^{3}H with frequency a function of the levels measured	Stream-above and below the facility; Reservoir, bay, lake - nearest shoreline; any nearby domestic water suppliers using the receiving waters as a raw water source
Bottom Sediments	Semi-annually	Gross beta and gamma scans	Near reactor's outfall or above and below the outfall if the receiving water is a stream
Ground Water	As applicable (usually quarterly or annually)	Gross beta and gamma scans	Supplies within 5 miles of the facility
Aquatic Biota	Variable	Gamma spectrum analysis for selected radionuclides	Near the reactor's outfall or above and below if receiving water is a stream
Food Crops and Other Vegetation	Season (before or at harvesting time)	Gamma spectrum analysis	Within a 10-15 mile radius of the facility
Soil	Annually	^{90}Sr and ^{137}Cs or gross beta	Prevailing downwind direction in nearest agricultural areas.

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CHAPTER VIII - AIR POLLUTION

Air pollutants play a vital and interrelated role with other environmental contaminants in effective water resources and land use management. It is, therefore, quite important in the planning and management of a basin's water and land resources that air pollution factors receive careful consideration.

The popular conception of a few years ago that air pollution and its effects were restricted or peculiar only to the heavy industrialized urban areas of the country has been thoroughly exploded and today it is well recognized that air pollution is of vital concern in suburban and rural areas as well. Air pollution is also not restricted to human effects but manifests itself in esthetic and social effects as well as effects on property, materials, and vegetation. Thus it is obviously clear that an effective grasp on control of air pollution must consider all the above interrelationships.

The control of air pollution must not only be meshed with the control of other environmental pollutants but be attacked on the basis of existing and future regional and urban growth patterns.

The purpose of this chapter of the Health Guidelines is to examine the various aspects of air pollution which should be considered along with other environmental factors in overall water and land resource management and planning.

NATIONAL AIR POLLUTION CONTROL MANAGEMENT

The leadership of the Federal government in air pollution control management is strongly established by the Clean Air Act.(1) Actual control and prevention of air pollution at its source, however, is the responsibility of State and local governments. The Federal government provides the research, financial assistance, and leadership for the development of effective State, regional, and local programs to prevent and control air pollution.

Federal authorities establish Air Quality Criteria (2)(3), define Control Techniques (4)(5), and designate Air Quality Control Regions. State authorities establish air quality standards (based upon Federal Air Quality Criteria) and establish implementation plans which call for the use of control techniques and which are designed to meet the standards within a specialized time frame.

AIR QUALITY CONTROL REGIONS AND RIVER BASIN PLANNING

Air Quality Control Regions (AQCR's) may or may not be contiguous with river basins and will overlap in some instances. These AQCR's are

designated on the basis of meteorological, social, and political factors which indicate that a group of communities should be treated as a unit for setting limitations on concentrations of atmospheric pollutants. In general, these AQCR's are centered on standard metropolitan statistical areas. Full development of the AQCR concept will allow for the eventual establishment of over 200 regions in the United States. Federal policy requires that air quality standards be established by State authorities for the AQCR's based upon the Air Quality Criteria and an implementation plan to achieve and maintain the standards within a reasonable time frame must be developed. In river basin planning these AQCR's should be considered and the applicable air quality control regulations evaluated for relationships to river basin planning.

TYPES AND SOURCES OF AIR POLLUTANTS

There are a wide variety of air pollutants which are present in the nation's atmosphere today.(6)(7)(8) The five most common pollutants in tons emitted per year are carbon monoxide, sulfur oxides, hydrocarbons, nitrogen oxides, and particulates. The major sources of these are motor vehicles, industrial plants, electric utility plants, space heating, and refuse disposal.

Air pollutants are emitted in a wide variety of quantities depending upon the source and operating conditions. As an example Table 1 shows that, except for nitrogen and sulfur oxides, considerably more pollutant quantities are emitted from back yard burning and burning dumps than from multiple chamber incinerators. Of course, virtually no air pollution results from properly constructed and maintained sanitary landfills.

TABLE 1
Relative Amounts* of Air Pollutants from Solid Waste Burning(9)

Pollutant	Multiple-Chamber Incinerator	Back Yard Burning	Burning Dump
Aldehydes	1	3	4
Benzo(a)pyrene(BaP)	1	60	40
Hydrocarbons	1	200	280
Nitrogen Oxides	1	0.25	30
Sulfur Oxides	1	0.4	0.5
Ammonia	1	5	8
Organic Acids	1	2.5	2.5
Particulates	1	17	5

*Relative amounts of pollutants were computed using the emission from multiple-chamber incinerators as 1 for each pollutant.

The National Air Pollution Control Administration has developed the following breakdown of air pollution sources:(10)

1. Fuel Consumption (Stationary Sources)

   a. Residential - includes space heating, water heating, and cooking fuels.

   b. Commercial-Institutional-Governmental - includes mainly space heating fuel.

   c. Industrial - includes space heating, process heating, and steam and electric production fuels.

   d. Steam-Electric Power Plants - includes steam and electric production fuels.

2. Industrial Process Losses - includes losses from all manufacturing processes.

3. Solid Waste Disposal

   a. Incineration

   b. Open Burning

4. Transportation (Mobile Sources)

   a. Motor Vehicles

   b. Aircraft

   c. Railroads

   d. Ships

EFFECTS OF AIR POLLUTANTS

The effects of air pollutants upon the environment(11) in which we live are becoming more evident and more people are expressing the need for eliminating these adverse effects. Some effects of particulates and sulfur dioxide which have been established can be summarized as follows:

Particulates

1. Effects on Health

Analysis of numerous epidemiological studies clearly indicate an association between high levels of air pollution, as measured by particulate matter together with sulfur dioxide, and the occurrence of health effects. This association is most firm for the short-term air pollution episodes. Conclusions which have been reached by various studies are:

a. At concentrations of 750 $\mu g/m^3$ and higher for particulates on a 24-hour average, accompanied by sulfur dioxide concentrations of 715 $\mu g/m^3$ and higher, excess deaths and a considerable increase in illness may occur.

b. If concentrations above 300 $\mu g/m^3$ for particulates persist on a 24-hour average and are accompanied by sulfur dioxide concentrations exceeding 630 $\mu g/m^3$ over the same average period, chronic bronchitis patients will likely suffer acute worsening of symptoms.

c. At concentrations over 200 $\mu g/m^3$ for particulates on a 24-hour average, accompanied by concentrations of sulfur dioxide exceeding 250 $\mu g/m^3$ over the same period, increased absence of industrial workers due to illness may occur.

d. Where concentrations range from 100 $\mu g/m^3$ to 130 $\mu g/m^3$ and above for particulates (annual mean) with sulfur dioxide concentrations (annual mean) greater that 120 $\mu g/m^3$, children residing in such areas are likely to experience increased incidence of certain respiratory diseases.

e. At concentrations above 100 $\mu g/m^3$ for particulates (annual geometric mean) with sulfation levels above 30 mg/cm^2-mo., increased death rates for persons over 50 years of age are likely.

2. Effects on Direct Sunlight

At concentrations ranging from 100 $\mu g/m^3$ to 150 $\mu g/m^3$ for particulates, where large smoke turbidity factors persist, in middle and high latitudes direct sunlight is reduced up to one-third in summer and two-thirds in winter.

3. Effects on Visibility

At concentrations of about 150 $\mu g/m^3$ for particulates, where the predominant particle size ranges from 0.2 μ to 1.0 μ and relative humidity is less than 70 percent, visibility is reduced to as low as 5 miles.

4. Effects on Materials

At concentrations ranging from 60 $\mu g/m^3$ (annual geometric mean), to 180 $\mu g/m^3$ for particulates (annual geometric mean), in the presence of sulfur dioxide and moisture, corrosion of steel and zinc panels occurs at an accelerated rate.

5. Effects on Public Concern

At concentrations of approximately 70 $\mu g/m^3$ for particulates (annual geometric mean), in the presence of other pollutants, public awareness and/or concern for air pollution may become evident and increase proportionately up to and above concentrations of 200 $\mu g/m^3$ for particulates.

Sulfur Dioxide

1. Effects of Health

Analyses of numerous epidemiological studies clearly indicate an association between high levels of air pollution, as measured by sulfur dioxide, accompanied by particulate matter, and the occurence of health effects. This association is most firm for the short-term air pollution episodes. Conclusions which have been reached by various studies are:

a. At concentrations of about 1500 $\mu g/m^3$ (0.52 ppm) of sulfur dioxide (24-hour average), and suspended particulate matter measured as a soiling index of 6 Cohs or greater, increased mortality may occur.

b. At concentrations of about 500 $\mu g/m^3$ (0.19 ppm) of sulfur dioxide (24-hour mean), with low particulate levels, increased mortality rates may occur.

c. At concentrations ranging from 300 $\mu g/m^3$ to 500 $\mu g/m^3$ (0.11 ppm to 0.19 ppm) of sulfur dioxide (24-hour mean), with low particulate levels, increased hospital admissions of older persons for respiratory disease may occur; absenteeism from work, particularly with older persons, may also occur.

d. At concentrations of about 120 $\mu g/m^3$ (0.046) of sulfur dioxide (annual mean), accompanied by smoke concentrations of about 100 $\mu g/m^3$, increased frequency and severity of respiratory diseases in school children may occur.

2. Effects on Visibility

At a concentration of 285 $\mu g/m^3$ (0.10 ppm) of sulfur dioxide,

with comparable concentration of particulate matter and relative humidity of 50 percent, visibility may be reduced to about five miles.

3. Effects of Materials

At a mean sulfur dioxide level of 345 $\mu g/m^3$ (0.12 ppm), accompanied by high particulate levels, the corrosion rate for steel panels may be increased by 50 percent.

4. Effects on Vegetation

a. At a concentration of about 85 $\mu g/m^3$ (0.03 ppm) of sulfur dioxide (annual mean), chronic plant injury and excessive leaf drop may occur.

b. At concentrations of about 145 $\mu g/m^3$ to 715 $\mu g/m^3$ (0.05 ppm to 0.25 ppm), sulfur dioxide may react synergistically with either ozone or nitrogen dioxide in short-term exposures (e.g. 4 hours) to produce moderate to severe injury to sensitive plants.

EFFECT OF AIR POLLUTION CONTROL ON OTHER ENVIRONMENTAL ASPECTS

In consideration of the air pollution aspects of regional environmental matters, careful attention must be given to the effects of air pollution control upon other environmental areas. Control techniques which reduce the amount of air pollutants discharged to the atmosphere usually result in an increase of materials which must be disposed of by other means. For example, wet collectors used for air cleaning devices result in water pollutants which may be discharged from facilities. Cartrell has given an excellent review of the water pollution potential of air pollution control devices. In this review he states that an impact on stream pollution has been experienced in almost every type of industrial situation where extensive air pollution control or abatement has been attempted. He cites air pollutants such as fluoride compounds from fertilizer, aluminum, steel, and uranium processing plants; sulfur compounds from smelters, power plants, coke plants, and refineries; particulates from power plants, blast furnaces, ferro-alloy, calcium carbide, and other types of plants; and radioactive wastes from atomic energy installations. (9)

In view of the significant effects which air pollution control can have on water pollution, solid wastes, and other environmental factors and the significant effects which water resource development can have on industrial development and other factors which may increase air pollution problems, it is imperative that air pollution aspects be considered in river basin planning and development.

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